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Last Roundup of Papers
See page 10

INSTITUTE OF FOOD TECHNOLOGISTS

FOOD TECHNOLOGY

PUBLISHED BY THE INSTITUTE OF FOOD TECHNOLOGISTS

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Precooked Frozen Stews and Swiss Steak

Effect of Spray Materials on the Quality of Canned and Frozen Montmorency Cherries

Affairs of the Institute

March, 1953 Pages 97-144 Volume 7, Number 3

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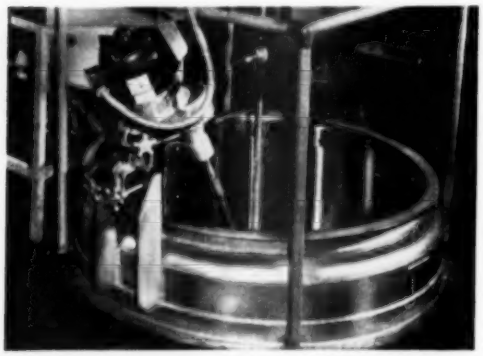

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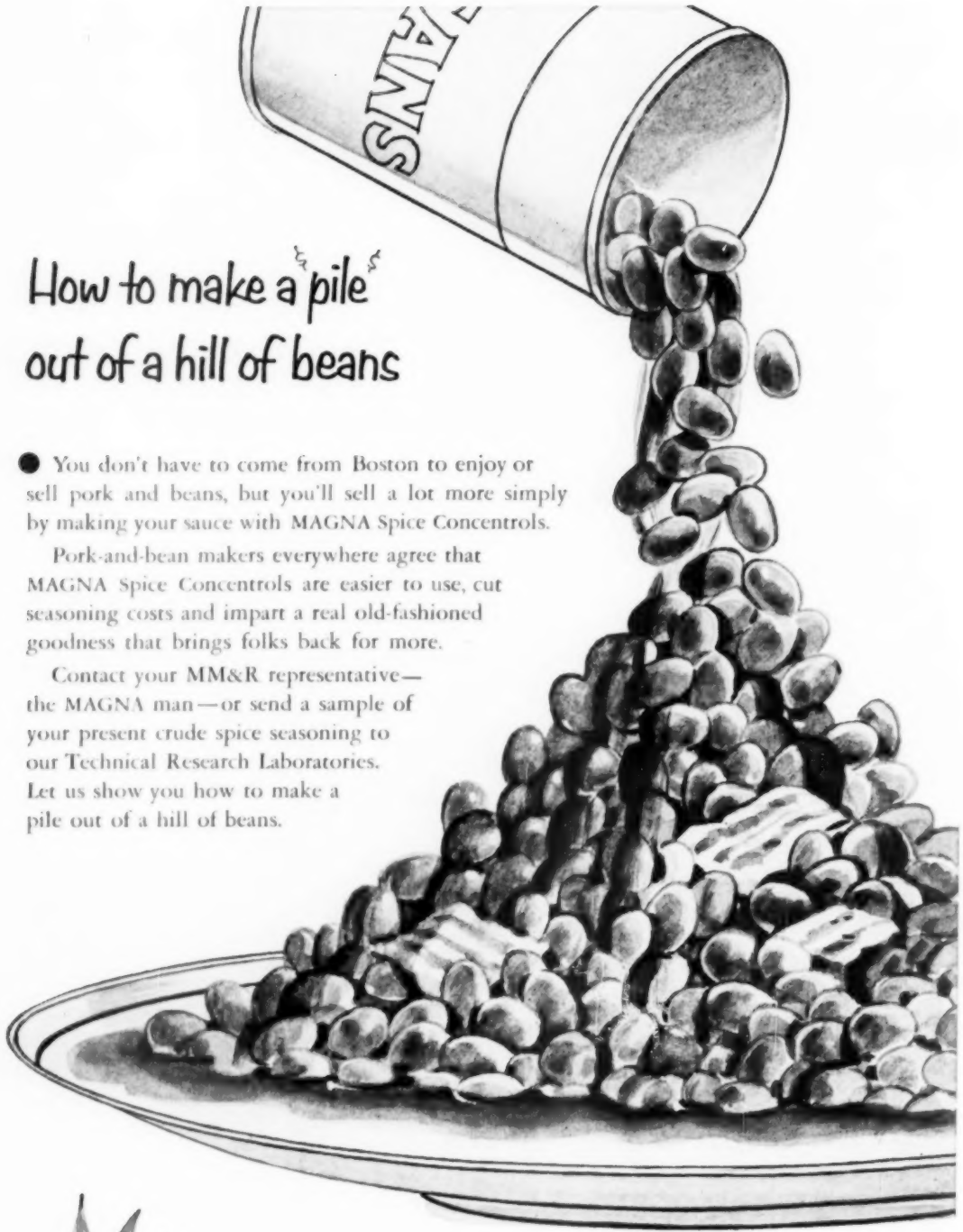

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Published Monthly by the Institute of Food Technologists

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Address to this office all manuscripts, proofs, letters pertaining thereto, etc. Prospective contributors are invited to send for the pamphlet *Information and Suggestions to Authors* which contains style instructions.

Responsibility for statements appearing in FOOD TECHNOLOGY rests on the author thereof; points of view expressed in the columns of the journal do not necessarily have the indorsement of the Institute of Food Technologists.

Office of the Business Manager

176 West Adams Street, Chicago 3

Address to the business office all requests for subscriptions, changes of address, and information on advertising. Claims for copies lost in the mails must be received 30 days after issue (90 days, foreign). Changes of address must be received at least two weeks before date of issue.

Subscription Rates: For members the cost of subscription is included in the annual dues. Non-members: domestic, $7.50 per year; foreign, $8.50 per year. Single and back copies: domestic, $1.00; foreign, $1.15.

Advertising Representatives: *Eastern:* Duncan Macpherson, 700 S. Washington Square, Philadelphia 6, Pa. *Midwestern:* Prendergast and Minahan, 168 N. Michigan Avenue, Chicago 1. *West Coast:* Duana Wanamaker, 610 S. Broadway, Los Angeles 14, California.

Publication Office

The Garrard Press, 119 West Park Avenue, Champaign, Illinois

Address to the Publication Office all requests for non-member subscriptions, back volumes, single copies (costs are listed above). Authors desiring reprints should address orders to this office; rates are printed on the order blank. (Requests for a single reprint of a published paper should be addressed to the author.)

FOOD TECHNOLOGY is published by the Institute of Food Technologists and printed by the Garrard Press, Champaign, Illinois, U. S. A.

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Mailing Permit: Entered as second-class matter, Feb. 25, 1947, at the Post Office at Champaign, Illinois, under the Act of August 24, 1912.

Volume 7 **March 1953** **Number 3**

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Affairs of the Institute

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What's New in Food Science Literature

This is the time of year when a brief survey of what's ahead in the field of food science literature is in order. Although not all of the publishing events of 1953 have as yet cast their shadows before them, a number either are or soon will be a part of scientific literary history.

The attractive new journal, *Applied Microbiology*, sponsored by the Society of American Bacteriologists and edited by H. Boyd Woodruff has made its debut. Devoted to the publication of articles in the microbiological field its coverage will include practical articles on microorganisms of interest to commerce because of their effect, harmful or benign, on industrial products. Bioengineering, food fermentation, industrial bacteriology relating to the brewing and baking industries, the production of antibiotics, the production of special organic chemicals by action of microbes, mycology, and plant sanitation—these are some of the topics to be exploited by the new journal. It will be issued bimonthly.

Attracting equally wide interest is the impending appearance of the new journal addressed to food chemists —*Agricultural and Food Chemistry*. This biweekly publication will be concerned with "the application of chemistry to the growth, production, and processing of foods." The subject matter of the new journal, which will make its initial appearance in April, will include investigations on "fertilizers, herbicides, pesticides, plant hormones, trace elements, etc." In addition to technical papers, the journal will carry scientific and industrial news. *Agricultural and Food Chemistry* is the seventh of the journals owned and operated by the American Chemical Society.

The entrance of these new learned journals into the field of food science is to be welcomed. That a certain amount of healthy competition of an indirect nature will ensue will doubtless be candidly admitted by all concerned. The net effect, however, should be to increase the quality, sharpen the discussion, and stimulate the production of papers benefiting the vast enterprise of growing and manufacturing food.

While on the subject of journals it might be timely to mention a publication which, though not new, deserves the attention of all who are at work on food research and development problems; namely, *Food Science Abstracts*. This publication, which emanates from the Department of Scientific and Industrial Research, Her Majesty's Stationery Office, London, is fulfilling an increasing need. Its coverage is broad and as the journal literature on food grows it will be found an indispensable ally in keeping investigators in this country and abroad aware of advances in food science and technology.

New Books from the Spring Lists

Although the publishers' spring lists are only just out at this writing, an inkling, at least, of what's astir can be provided.

In the chemical field, of the many spring books with interest for food technologists mention should be made of F. Wild's *Estimation of Organic Compound*, Cambridge University Press, scheduled for April; J. B. Sumner and I. Fred Somers' *Chemistry and Methods of Enzymes* (3rd. ed., Academic Press); P. Honig's *Chemical and Physical Principles of Sugar Technology*, (Elsevier) to be published in April; Morris B. Jacobs and Leopold Scheflan's *Chemical Analysis of Industrial Solvents* (Chemical Analysis, Volume 7, Interscience Publishers); R. L. Whistler and C. L. Smart's *Polysaccharide Chemistry* (Academic Press); and *The Proteins*, Vol. I, Kenneth Bailey and Hans Neurath, editors, which will be issued in May by the same publishers.

Olaf Samuelson's *Ion Exchangers in Analytical Chemistry* (Wiley) appeared in February. The book is devoted exclusively to the application of the new synthetic organic ion-exchangers. Another Wiley book scheduled for April is Joseph S. Fruton and Sofia Simmonds' *Textbook of Biochemistry*, wherein the structure of modern biochemistry is presented from a general point of view. The book will contain 950 pages. Jacob Sack's *Isotropic Tracers in Biochemistry and Physiology* (McGraw) will be published in May.

Statistical methods are by no means to be neglected in 1953. There are several books on this topic in the spring lists; namely, O. L. Lacey's *Statistical Methods in Experimentation* (Macmillan), C. E. Clark's *Introduction to Statistics* (Wiley), and V. Goedicke's *Introduction to the Theory of Statistics* (Harper). *Mathematical Methods for Scientists and Engineers* (Prentice-Hall) by Lloyd P. Smith should also be noted in connection with statistical methods literature.

In the field of nutrition there are G. H. Bourne and G. W. Kidder's *Biochemistry and Physiology of Nutrition*, Vol. I, (Academic Press) which will be published in April and A. R. Anderson's *Essentials of Physiological Chemistry* (Wiley).

Faber and Faber, Ltd. of London have also announced two books in the field of nutrition. One is Sir Robert McCarrison's *Nutrition and Health*, a new edition of this key work on the relation between food and good health. Two additional essays—on deficiency diseases—are added. The second book, *The Work of Sir Robert McCarrison*, is edited by Dr. H. M. Sinclair. The latter book is being published to honor this famous scientist upon his seventy-fifth birthday. The volume (a) describes the initiation and development by Sir Robert of the Cooner Nutrition Research Laboratories, (b) provides in outline the historical setting of his research and (c) appraises its present importance.

Another British publishing house, the Food Trade Press, Ltd. carries the following four books on its 1953 list: *Practical Canning* by Arthur Lock; *Potato Crisps* (Chips) by A. E. Williams; *A Course in Canning* by John L. Rogers; and *Macaroni Products* by Charles Hummel.

(Continued on page 6)

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What's New in Food Science Literature

(Continued from page 4)

The Princeton University Press is publishing O. E. Anderson's *Refrigeration in America* in June.

A book treating a special technology, *Fishery Science* (Wiley) by G. A. Rounsefell and W. Harry Everhart, will appear in May.

Of wide interest to the membership was the appearance in February of *Advances in Food Research*, Vol. 4 (Academic Press) edited by two IFT members, Dr. Emil Mrak and Dr. George F. Stewart of the University of California. M. S. P.

Regional Section News

CHICAGO SECTION

The January 1953 meeting of the Chicago Section was held January 12th with the guest speaker Dr. Nelson Allen Ass't. Mgr., Sales Development and Technical Service E. I. Du Pont De Nemours and Company.

Subject: "Packaging of Perishable Products."

Born in Franklin, Kentucky, Dr. Nelson Allen received his degree of bachelor of arts in chemistry from Centre College, Danville, Kentucky. Completing several years of teaching at Centre, Dr. Allen joined the research department of the Du Pont Company, later resigning to accept a fellowship at Princeton University. At Princeton he received his master's degree in 1932 and in 1933 his doctorate in chemistry. Dr. Allen returned to the Du Pont Company as a research chemist in the viscose rayon research section. He later took an active part in cellophane research package engineering and sales development. Dr. Allen assumed his present position in January, 1952.

With the rapid growth of self-service during the past few years, proper packaging has taken on more and more significance. The proper packaging of perishable products has become a challenge to food technologists in all phases of manufacturing and selling. With perishables close attention must be given to film with optimum transfer of moisture and gas—particularly oxygen. Packages cover the range of films with high transfer of moisture for products such as hard crusted bread to a film on which a vacuum can be pulled and maintained.

Some specific packaging problems were described including those of products such as bakery goods, cheese, meats and produce.

With the advent of well-engineered packaging, the trend has been for packaging to be done at the point of production of product rather than by the retailer. This introduces additional storage and transportation problems, accentuated by the respiration constantly going on in the living matter that is being packaged.

Cellophane with various treatments and laminations was described as being the ideal product for most applications.

BRITISH COLUMBIA SECTION

Activities of the Section in rapid review are:

The first Fall Meeting consisted of a luncheon and plant tour at the American Can Company plant in Vancouver on Wednesday, September 10, 1952. After a delightful meal, Mr. B. G. Coles, the Assistant Plant Manager, described the operation of the plant to the members, who were later conducted through the entire plant.

The October meeting was held at Edith Adam's Cottage in the Vancouver Sun Building, on the 29th; the speaker was Dr. L. E. Ranta, whose subject was "Food Technology and Public Health."

The November meeting took place at the Vancouver Vocational Institute, on the 19th, and the subject discussed was "Spices and Food Technology," by Mr. Maurice Rector, Vice-President of Griffith Laboratories, Toronto, Ontario. Koda-Chrome slides were used to illustrate the talk.

The Fall Session came to a close when the Section Members joined with the Vancouver group of the Canadian Institute of Chemistry at the Gai Paree on December 17th, 1952.

The first meeting in 1953 was held on January 29th, when Mr. Angus McIntyre of the B. A. Paint Company in Victoria, B. C. discussed "Paints in the Food Industry," a topic which is of great interest to food technologists. Mr. McIntyre is one of the outstanding paint chemists in Canada.

DIXIE SECTION

The first meeting of the new year of the Dixie Section of IFT was held at the Atlanta Paper Company on January 23, with possibly the best attendance of any meeting this Section has ever held.

During the afternoon a tour was made of the Atlanta Paper Company, showing the methods of manufacturing, many types of containers, particularly the package for carrying home bottled drinks that has become very popular in recent years. A new type of extremely white, greaseproof chip board was described as having many possibilities.

Dinner was served for approximately 100 members and visitors by the host company, after which Mr. Norman Eppell of the Chicago Quartermaster Food and Container Institute delivered an exhaustive report on the behavior of containers for Five-in-One and Combat Rations, stored under widely different conditions of temperature and humidity. Most of the report was of results obtained from experiments now being conducted at the Georgia Experiment Station.

The present officers of the Dixie Section believe that this will be the most successful year in the history of the Section.

GREAT LAKES SECTION

The Section held its Winter Meeting on January 23rd, at the Hillcrest Hotel, Toledo, Ohio. In the morning a tour was made of the Libbey Glass division of the Owens-Illinois Glass Company, following which an Executive Committee luncheon was held at the Hillcrest Hotel. In the afternoon, at the Duraglass Center, Adams and 14th Streets, the following papers were heard:

"They Never Suspected." A nutrition study of 75 typical families in the Philadelphia area. Miss Camille Beauchamp, Assistant Manager, Home Economics Institute, Westinghouse Electric Corp.

(Continued on page 8)

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Regional Section News

(Continued from page 6)

"Vitamin and Amino Acid Assays by Microbiological Procedure." Dr. C. W. Christensen, Associate Director, Bacteriological Laboratories, Difco Laboratories, Detroit, Michigan.

"Modern Food Poisoning." A discussion of the causes and modern methods of preventing food poisoning. Dr. H. O. Way, H. O. Way Laboratories, Cleveland, Ohio.

The evening dinner speaker was Mr. Walter F. Wargell, Vice-President, Strong-Cobb Co., Cleveland, Ohio, who spoke on "And the Grass Grew Green All Around"—a discussion of chlorophyll and its application in the food and drug industries.

NORTHEAST SECTION

The Section's February meeting was held on the 5th, at the Hotel Brunswick, Boston, Mass., when Dr. Aksel G. Olsen, General Foods Corporation, Central Laboratories, Hoboken, New Jersey, was the guest speaker. His subject was "The Smorgasbord of the Scandinavian Food Factory"—a talk on the food technology and food industry in the Scandinavian countries. Dr. Olsen discussed the status of food research, the effect of natural resources, and size of population and its food habits on the food technology and food factory operations. In addition, he showed pictures of food plants and food processing—particularly in Sweden.

WESTERN NEW YORK SECTION

The Western New York Section, Buffalo Area, met on January 19th, 1953, at the New York State Institute of Applied Arts & Sciences in Buffalo, New York. The guest speaker at this dinner was Dr. M. D. Labee, the Rohm & Haas Company, Philadelphia, Penna., who spoke on "Enzymes—Their Nature, Commercial Production and Usages." Since Enzymes, either as friend or foe, are of fundamental importance to the food technologist, Dr. Labee's discussion was most interesting and timely.

SOUTHERN CALIFORNIA SECTION

Eleda's Restaurant in Los Angeles was the scene of the December and January meetings of the Southern California Section.

At the December 17th meeting, Section Chairman announced that the 1954 Annual Meeting will be held in the Los Angeles Biltmore Hotel, and urged all members to contract for space well in advance. Treasurer, Roy M. Hagen, resigned his office in order to devote full time to his duties as President of the Los Angeles Chamber of Commerce.

Mr. Ford Sammis, Los Angeles Market Economist spoke on "Market Research in the Food Field." The speaker covered the function of the market research specialist in the development of markets for new products and in the expansion of markets for established products. It was his opinion that the food industry should use market research as any other research tool and should have periodic and supplemental surveys of its markets.

On Jan. 21 Prof. T. A. Geissman of U. C. L. A., spoke on the chemistry of coumarin derivatives found in cold pressed oil of citrus and other genera of the Rutaceae family. The chemistry of bitter substances in citrus fruits, including peel, seeds, juice and pulp was also discussed. The principal bitter compounds are limonin, nomilin and abacunone. They are compounds which are not well understood from the chemical standpoint and offer a real challenge to the ambitious organic chemist.

Attention, chemists attending Los Angeles A. C. S. meetings. The Southern California Section of the Institute of Food Technologists, holding their annual all day conference on Friday, March 13, 1953, at the Statler Hotel in Los Angeles, are planning to look behind the curtain that veils the future and see what's ahead in the way of food science. The program, written out in one sentence, is as follows:

Food Technology as of March 13, 1953 and Beyond:
We've approached food technology with new and scientific methods in recent years and we are permitted re-evaluation of some basic "mainliner" components such as:

"Mainliner Protein" (D. M. Doty) and
"Mainliner Fats-Oils" (Walter O. Lundberg) and
"Mainliner Carbohydrates" (Harry S. Owens) and
certainly not a side track or whistle stop the vitamin and mineral and other supplementals,
"Major Minors" (Harry J. Deuel);
all of these four have the possibility of existing in reasonable harmony together or are capable of the browning or other "Reactions" (Bernard L. Oser),
depending in large part on storage, packaging and care in "Processing" (L. E. Clifcorn),
all of which prepares us well to consider
"Is the World Facing Starvation" (Albert L. Elder).

"Mainliner" speakers hail from many sections: D. M. Doty is Assistant Director of Research and Education, American Meat Institute Foundation, Chicago, Illinois; Walter O. Lundberg directs the Hormel Institute of the University of Minnesota, Minneapolis; Harry S. Owens heads the Carbohydrate Section of the Biochemical Division, Western Regional Research Laboratory, Albany, California; Harry J. Deuel is Dean of the Graduate School of the Univ. of Southern California at Los Angeles; B. L. Oser operates the Food Research Laboratories, Inc. located in Long Island City, New York; L. E. Clifcorn is Director of the Fundamental Research Division of the Continental Can Company, Inc. in Chicago, and A. L. Elder is Director of Research, Chemical Division, Corn Products Refining Company at Argo, Illinois. Food chemists headed for the American Chemical Society meetings in Los Angeles may wish to start a few days early to catch the "Mainliner" meeting at the Statler Hotel, Los Angeles, on March 13.

PERSONNEL

DR. M. J. BLISH, supervisor of organic and biochemical research for International Minerals & Chemical Corporation has received the University of Minnesota's outstanding achievement award. The award is reserved for former students of the Minnesota institution who have attained high eminence and distinction. Dr. Blish's research work in the fields of cereal technology, proteins, enzymes of wheat and flour, and the commercial production of amino acids, especially glutamic acid, has

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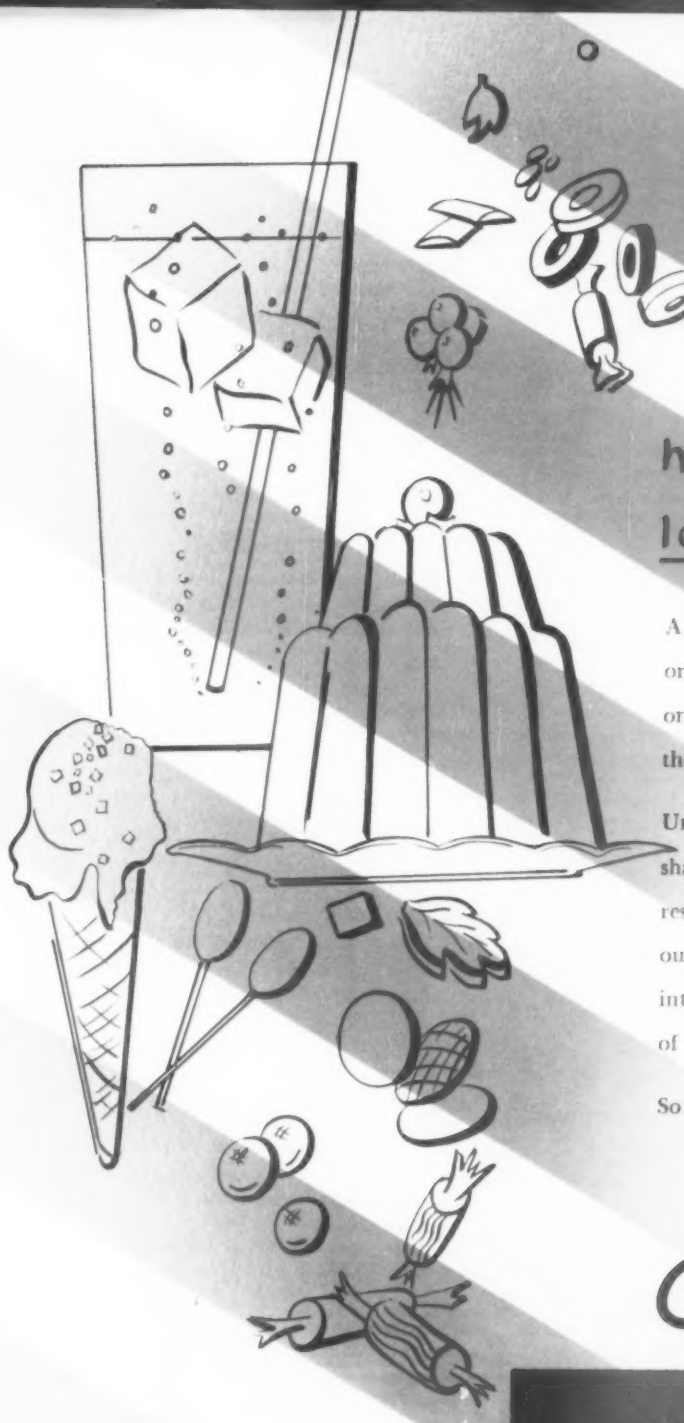

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Regional Section News

(Continued from page 8)

won him wide recognition. In 1936 he received the Thomas Burr Osborne medal of the American Association of Cereal Chemists. He has served as president of that organization, is a fellow of the American Institute of Chemists, and is a member of the American Association for Advancement of Science, the American Chemical Society, the Institute of Food Technologists, and the American Society of Biological Chemists and the New York Academy of Sciences. Dr. Blish received his bachelor of science degree from the University of Nebraska and a doctor of philosophy degree in agricultural biochemistry from the University of Minnesota.

WOLFGANG HUBER, *Ph.D.*, Vice President in charge of Research and Development at Electronized Chemicals Corporation in Brooklyn, has been elected a Fellow of the New York Academy of Sciences. Nomination to Fellowship in the Academy is made by its Council "in recognition of outstanding scientific achievements."

DR. AGNES FAY MORGAN of the University of California will head a round table of nutritionists who will explore "Food Facts and Fads in the Light of Recent Research" at the Fourth Biennial Convention and Exhibition of the California Home Economics Association in San Francisco, March 28-30. The nation's leading manufacturers of appliances and other equipment will feature their latest products.

W. M. FOSDICK has joined Dales Restaurants, Birmingham and Montgomery, Alabama, and is presently hard at work setting up quality control measures, standardizing menus and cutting procedures. He will manage the Atlanta restaurant personally but his responsibilities will extend to the other Dale's restaurants including those about to be opened.

Once again FOOD TECHNOLOGY welcomes to the Editorial Board sanctum a panel of new editors—each of whom has consented to give time, thought, and energy from a busy life to the task of maintaining the standards and prestige of the journal during the next three years. The new editors are: DR. WILLIAM R. JOHNSTON (Standard Brands Inc.), DR. WALTER A. MACLINN (Rutgers University), DR. HELEN L. HANSON (Western Regional Research Laboratory), DR. GEORGE A. CRAPPLE (Wilson and Co.) and DR. ROBERT E. BUCK (H. J. Heinz Co.). MR. C. HAMILTON KENNEY (Department of Agriculture, Ottawa, Canada) has consented to reappointment for a three-year term and will carry on the function of gathering and editing news of the regional section.

Announcement of Samuel Cate Prescott Award Competition for Student Members of the Institute of Food Technologists

The "Samuel Cate Prescott Award" in Food Technology was established by the Northeast Section of the Institute of Food Technologists to honor Doctor Samuel C. Prescott, outstanding researcher in the field of food technology.

This Award is presented annually to the person entering, in competition, the best written account of a research project in the field of food technology, preferably, but not necessarily, a project conducted by the author.

Those eligible for the competition include all student members of the Institute of Food Technologists in good standing, or persons who were seniors during the academic year 1952/53, and who received a Bachelor's degree in Food Technology prior to July 1, 1953.

The prize shall be $100.00.

Competitors are to submit their written papers to the Institute of Food Technologists, 176 West Adams Street, Chicago 3, Illinois, previous to September 1, 1953.

ANNUAL MEETING PAPERS—LAST ROUNDUP!

The program of technical papers to be presented at the annual meeting in Boston, June 21-25, is being rapidly rounded out. However, if you act at once, there is still room on the program in most of the sections. *Short papers are preferred.* You are requested to send in your abstract without delay to J. Avery Dunn, Atlantic Gelatin Division, General Foods Corp., Woburn, Massachusetts.

Obituary

With deep regret we report the death of E. S. Stateler on February 2, 1953. Born in Minneola, Kansas, in 1890, Ernest S. Stateler received his B.S. from the University of Kansas and his M.S. from the University of Pittsburgh. After serving as food chemist for the State of Kansas and as Fellow at the Mellon Institute, he received valuable industrial experience with E. I. du Pont de Nemours, where he was supervisor of the dye works. Later, he was with the Eatmor Chocolate Company, first as chemist and later as plant superintendent. Author of many articles on food technology, Mr. Stateler was former technical editor of *Food Industries*. He was, perhaps, best known for his years of active service with the Chicago Section of the Institute of Food Technologists which he helped to found. He became Chairman of the Chicago Section in 1948. At the time of his death Mr. Stateler was Food Consultant to the Wahl-Henius Institute and Professorial Lecturer in Food Engineering at the Illinois Institute of Technology. He was co-author of *Elements of Food Engineering*, which was issued late in 1952. The Institute and the profession of food technology generally has sustained the loss of an able and valued colleague.

Books

CHEMISTRY OF FOOD AND NUTRITION. Eighth Edition. Henry C. Sherman. 721 pages. The Macmillan Company, New York, 1952. Price $6.00.

Over forty years ago, when the first edition of *Chemistry of Food and Nutrition* appeared, Dr. Sherman made a notable contribution to the then young discipline of nutrition by presenting the various aspects of the subject and calling attention to the then established facts in the field and in pointing out the many gaps in

(Continued on page 15)

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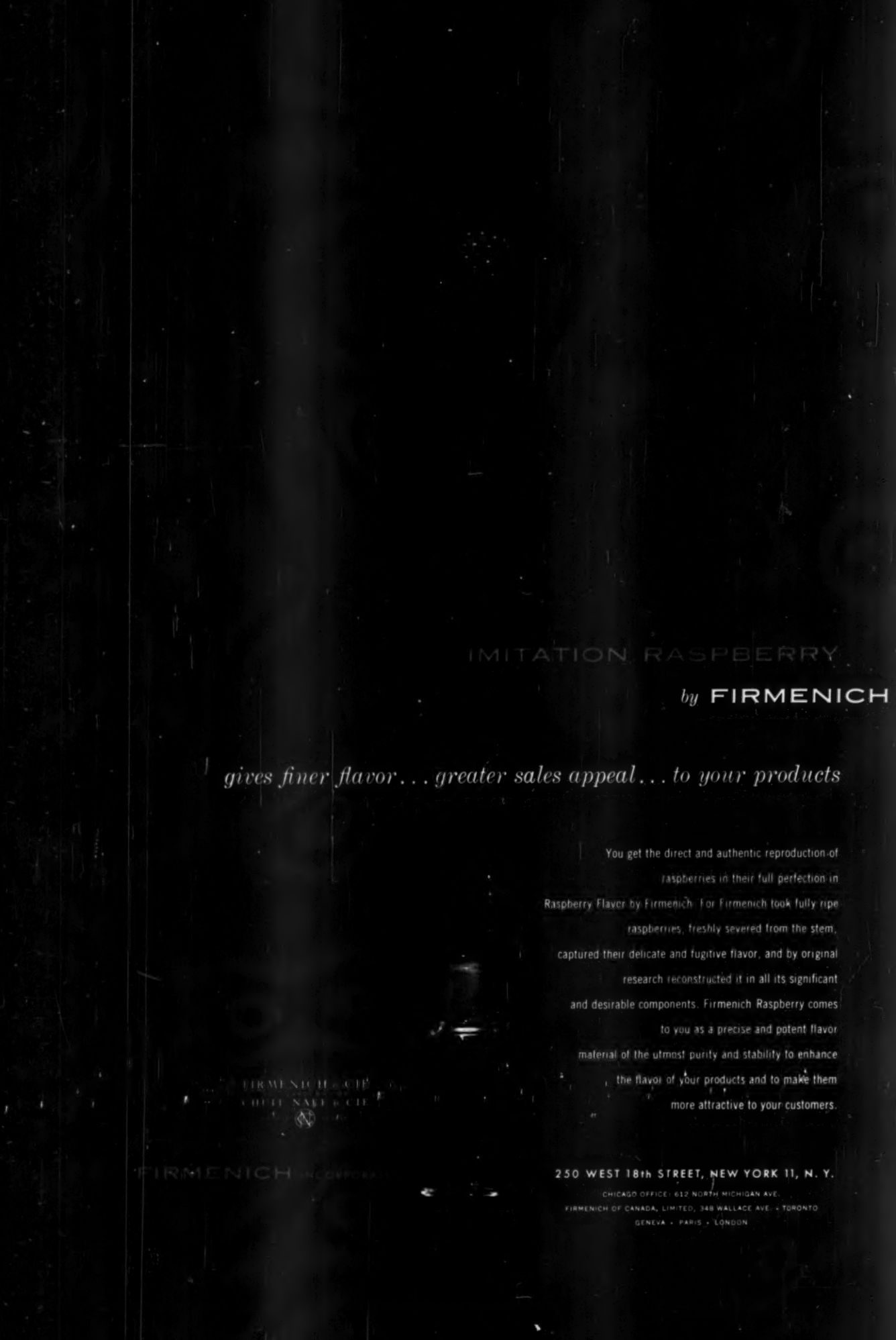

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Books

(Continued from page 10)

our knowledge that existed. His book had a most salutary effect in focusing attention upon the broad field of nutrition and did much to stimulate interest. The importance of his contribution is exemplified in the wide acceptance of his work and in its continued revision over the years. Our knowledge of food chemistry and of nutrition has increased greatly since 1911 and has been stimulated particularly by World War II and the establishment of the Food and Agricultural Organization of the United Nations. With the rapid development in the field, particularly in the last 15 years, a considerable amount of specialization has occurred and many comprehensive and authoritative treatises on particular aspects of food chemistry and nutrition have appeared. It is more difficult today than it was in 1941, when the sixth edition of the Chemistry of Food and Nutrition appeared, for one individual to authoritatively and critically present the background and present status in this rapidly growing field. This Professor Sherman has attempted to do.

In the eighth edition, similar in scope to the seventh, Professor Sherman has presented the subject matter in six major aspects: (1) energy relations of nutrition, (2) chemistry of proteins and protein chemistry of nutrition, (3) mineral elements in nutrition, (4) vitamins and vitamin aspects of nutrition, (5) interrelationships between energetics, protein, mineral elements and vitamins, and (6) food value and nutritive value during an entire life cycle of an individual or of a family, community or nation through successive generations. Of the 34 chapters, twelve are devoted to presentation of the basic chemistry of carbohydrates, fats and lipoids, proteins, minerals and vitamins; two to a general discussion of enzymes, digestion and the metabolism of foodstuffs; three to energetics; and the rest to various aspects of nutrition.

The material on the chemistry of food constituents is presented in simple language and is not as authoritative, complete and up-to-date as it is in the several recently published monographs on carbohydrates, proteins, lipids, etc. Intermediary metabolism is not discussed because it is felt to belong to general biochemistry and not to the field under review. Knowledge of organic chemistry is presumed but in the discussion various levels of this knowledge are implied. It is in the last eight chapters dealing with the fifth and sixth aspects that the material is more provocatively and interestingly presented.

The textual material is surprisingly free of typographical errors; the only ones noted were in the bibliography, where some of the references are incomplete and others are erroneous as, for example, the reference to Deuel's new monograph on *Chemistry of Lipids* as the 2nd edition (p. 42). While the references are copious they are not always complete or selected with equal care.

The work is recommended to food chemists and food technologists as an interesting integration of several aspects of nutritional chemistry and represents a summation of our present knowledge of the field from the viewpoint of one who contributed much to it.

M. A. JOSLYN.

INTRODUCTORY MYCOLOGY: By Constatine John Alexopoulos. 482 pages. John Wiley & Sons Incorporated, New York.

In writing this book the author's objective was to answer the question: (What are fungi and how do they affect us?) for the student in agriculture or bacteriology and also for those of more general training who have no time, and no desire to enter into the intricate details of mycology. The author has accomplished his objective exceedingly well. In fact, the usefulness of the book certainly extends beyond the group indicated above, to anyone who has had some biological training (particularly to Food Technologists) and is just interested in obtaining some knowledge of fungi. The entire book (including preface) is presented in an interesting, easy reading, and understandable manner.

The inclusion of the derivations of mycological terms in the text at the time when such terms are first used is unique and highly advantageous over the conventional and inconveniently located and commonly used glossary.

A modern and satisfactory classification is followed, though, as is true of any system, it is not necessarily free from controversial points.

Chapters are devoted to bacteria *(Shizomycophyta)* and the slime molds *(Myxomycophyta)* in order to orient the reader to these two large groups of organisms of interest and importance to the mycologist. In order to have a rounded knowledge of mycology, it is important to have some understanding of where these organisms fit into the general schemes of taxonomy, and how, and if, they are related to the fungi discussed more intensively in the book.

Subsequent parts of the book are devoted to the *Phycomycetes, Ascomycetes, Deuteromycetes, Basidiomycetes,* and *Lichens.* The general arrangement is very logical and the partitioning into chapter is such that the book is easy to follow by a person with a limited knowledge in biology.

The devotion of 27 pages to the form class *Deuteromycetes (Fungi Imperfecti)* has merit. Most books seem to avoid these organisms, which are frequently quite difficult to treat taxonomically. A chapter devoted to these organisms is located directly following the treatment of *Ascomycetes.* This has considerable merit, since most of the imperfect fungi are related to perfect forms of *Ascomycetes.* In the reviewer's opinion, a little clearer picture of what the imperfect fungi are, might have been given on page 312. It is indicated here that *Fungi Imperfecti* are conidial stages of *Ascomycetes* or more rarely *Basidiomycetes,* whose sexual stages have not been discovered or no longer exist. On pages 318, 319, and others, reference is made to the form order *Mycelia Sterilia.* The definition given on page 312, is not compatible with reference to the organisms in the form order *Mycelia Sterilia.* Such inconsistencies are minor and do not detract from the value of this book.

The line drawings and illustrations merit comment. Such diagrammatic presentations give the reader an excellent opportunity to understand life cycles and morphological structures better than by discussions or photographs. In certain cases, more extensive labelling would have been helpful to the uninformed reader. A specific example is on page 215, where the dicaryophase

Books

of *Taphrina deformans* is illustrated. The location of the ascogenous cell is shown but it is not indicated as to whether or not the cell below is of host tissue. Presumably it is.

In connection with the discussion of the yeast, it would have been well to include a diagram of pseudomycelium such as is found in the genus candida. Reference is made to a pseudomycelium in figure 3 but this is an atypical structure, for this pseudomycelium certainly differs from those used so extensively in differentiation of certain genera of imperfect yeast. This, however, is not a serious omission but perhaps a minor criticism that seems to be essential if a reviewer is to be impartial. A limited bibliography is given at the end of each chapter. The references are mostly in English, which is important to a person not informed in the field.

The book is well bound, printing is excellent, and, as indicated above, illustrations are good. It is recommended for those who understand biology and wish to obtain some knowledge of fungi.

ELEMENTS OF FOOD ENGINEERING, Volume I. By Milton E. Parker, E. S. Harvey, and E. S. Stateler. 386 pages. Reinhold Publishing Corporation, New York. Price $8.75.

This book is the first of a three volume series planned to cover the field of food engineering. Volume I is a description of the food technology field explained from an engineering point of view. Thus, the major food industries are considered not only as to what they produce but also in terms of the unit operations and unit processes used in the production process.

It is the aim of the authors to discuss plant layout, equipment design, production efficiency, and sanitation in Volumes II and III—to be published later.

Volume I begins with a chapter on the engineering factors in food processing. This is followed by chapters discussing the agricultural and nutritional aspects of food processing, foods and foods processing in general, and the food processing industry.

The next nine chapters are concerned with refined food processing. They are wheat and corn flours—rice and oats milling—minor cereal flours—fats and oils—sugars, syrups, starches, and gums—food protein derivatives—spices, essential oils, condiments, and flavoring extracts—beverages and fermentation products—nuts.

Anyone who turns to this first volume for specific engineering information which can be used for calculation purposes will be disappointed. But for its objective—to describe and define the field of food engineering, it is well done and well worth having. It is, to the limit of the reviewer's knowledge the first book of its kind in the food field and has long been needed.

ROBERT A. LARSEN.

REFRIGERATING DATA BOOK, APPLICATIONS VOLUME (4th edition), edited by H. C. Diehl, American Society of Refrigerating Engineers, New York, N. Y., 1952. 950 pages. Price $7.50.

This is the third revision of the *Refrigerating Data Book, Applications Volume*. All chapters have been given critical scrutiny by the several technical committees of the Society and on the basis of these reviews the revisions have been made. Sixty-five authors, all recognized experts in their different fields, are represented. Several chapters have been completely rewritten to combine closely related subjects and to make the subject matter conform with the latest practice in refrigeration applications. Entirely new are the chapters on comfort air conditioning of railroad passenger cars, and supplements to refrigeration in warehouses; other chapters have also been completely recast.

Bibliographies are found throughout the book, providing source materials of unusual scope. This additional information for those interested in delving further into particular subjects will be found a most convenient feature of the book. For locating subject matter in the book more easily, the index has been enlarged to include more headings, subheadings, and cross references. A feature of great practical service is the Refrigeration Classified Directory, which provides ready references for those seeking lists of suppliers and manufacturers of equipment, component parts, and materials. Every effort has apparently been made to insure accuracy and completeness in this section.

Under the direction of Editor-in-Chief Dr. H. C. Diehl, and his eight associate editors, the eight major sections of the 4th edition of the *Applications Volume of Refrigerating Data Book* furnish a comprehensive coverage of the application of refrigeration. These sections comprise in well-organized form the latest information on Frozen Foods, Refrigeration in Food Manufacture, Refrigerated Warehouse Practice, Refrigerated Food Distribution, Low Temperature Applications, Industrial Applications of Refrigeration, Comfort Air Conditioning, and Industrial Air Conditioning.

M. S. P.

Selected Abstracts*

ANALYTICAL METHODS

Displacement chromatography on synthetic ion-exchange resins.
PARTRIDGE, S. M., AND BRIMLEY, R. C. *Biochem. J., 51,* 628-39 (1952).

A systematic procedure is described for the fractionation and isolation of amino-acids and bases using displacement chromatograms carried out with synthetic ion-exchange resins. The procedure is illustrated by 2 model expts. In the first example 16 amino-acids were isolated from 280 g. of com. egg albumin with an overall recovery of 54% of the dry wt. of protein taken. In the second example 10 g. of a protein derived from yeast were hydrolyzed and fractionated. Thirteen cryst. amino-acids were recovered, the total wt. representing 60% of the dry wt. of the protein. A new procedure for the isolation of threonine and serine is described. The relationship between the dissociation costs of a solute and its position in the sequence of displacement is discussed.

Paper chromatography of the ortho-, pyro-, meta-, and polyphosphates.
EBEL, J. P., AND VOLMAR, Y. *C. R. Acad. Sci., Paris, 233,* 415-17 (1951); *Brit. Abstracts, C, 377* (1952).

Paper-chromatographic procedures for the sepn. and micro detn. of ortho-, pyro-, meta-, and poly-phosphates are detailed.

* These Selected Abstracts are made available to FOOD TECHNOLOGY through the cooperation of Associate Editor H. A. Campbell and the General Foods Corporation of New York, N. Y. The abbreviations found in these abstracts are similar to those used by Chemical Abstracts.

(Continued on page 20 following technical papers)

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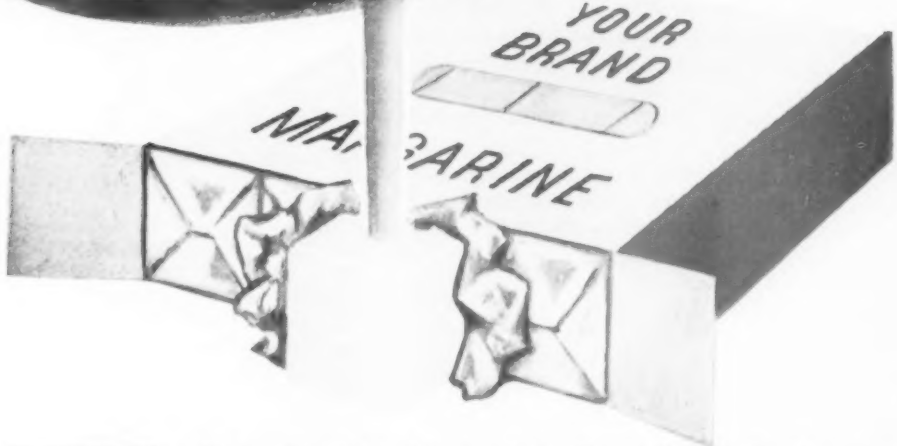

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The Vital Story of RICE ENRICHMENT

by Science Writer

The story of rice enrichment begins in the Philippines in 1910. In that year and place, Dr. R. R. Williams encountered the clue that started him on the road to the first successful synthesis of thiamine (vitamin B_1) in 1936. It was the curative effect against beriberi of an extract of rice polishings.

The problem of beriberi, while not serious in the United States, is recognized as severe, with high mortality, in the Philippines and other Asiatic countries where the population exists principally on white rice.

It is known that beriberi is caused by dietary deficiency and that factors in those parts of the rice which are removed in the milling are effective in combating the disease.

If rice could be milled to the whiteness desired by rice eaters and, at the same time, be made to contain the anti-beriberi factor, a giant stride could be taken to improve the health of rice-eaters. The use of white rice by these peoples, coupled with illness and death from beriberi, poses a problem for public health officials.

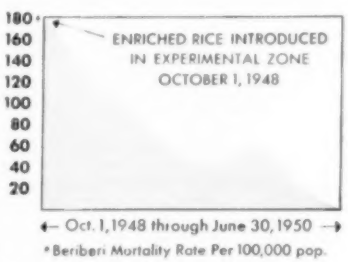
The answer to this problem was found in the laboratories of Hoffmann-La Roche. The researchers discovered a process by which white rice could be fortified. The method employs coatings of thiamine, niacin, and iron on rice grains and a final, outer coating of edible material to protect the vitamins against deterioration and preliminary washing and rinsing. For economy, large amounts of vitamins are applied to small amounts of rice to make a "premix." One pound of this enrichment premix is then mixed with each 199 lbs. of ordinary milled white rice at the rice mill. Each 8 ounces of this nutritionally-improved rice provide 1 mg. of thiamine, 8 mg. of niacin and 6.5 mg. of iron. These levels are commonly used but higher levels are easily obtainable.

A research project was established to study the effect on health of feeding white rice so enriched to a *population* in the Far East. Through the cooperation of the Government of the Philippines, the U. S. Public Health Service, the Williams-Waterman Fund, the Philippine National Rice and Corn Corporation, and Hoffmann-La Roche, a controlled experiment on the Bataan peninsula was set up. Medical examinations, under the direction of Dr. Juan Salcedo, now Secretary of Health for the Philippine Republic, were made of more than 12,000 people in the area before the enrichment of rice began. Nearly 13% had beriberi but most were symptom free a year later.

Enriched white rice was put into commerce in the experimental area, after full publicity about the program, on October 1, 1948. Careful monthly records were kept of the mortality from beriberi in the experimental and control areas.

The results of the test proved overwhelmingly the value of enriched white rice.

At the end of 2 years, with over 90,000 persons under this great nutritional test, the beriberi mortality rate per 100,000 population had dropped from approximately 190 in the experimental area to zero! And, from the evidence of the medical examinations, it was found that almost 90% of those who had displayed beriberi symptoms earlier were now free of them or greatly improved. Literally thousands of people were helped to better health.



The vital story of the Bataan experiment shows once again the value of enrichment to *entire peoples*. The moral is obvious: when good foods are made better, everyone benefits.

Published in the interests of better health through better nutrition by the Vitamin Division, Hoffmann-La Roche Inc., Nutley 10, New Jersey. Reprints of this article are available on request, without charge.

Efficacy and Specificity of Chemical Food Preservatives[a]

MATHILDE VON SCHELHORN

(Manuscript received May 20, 1952)

I. Introduction. This report is a review of the literature and the writer's research work *(1-7)*. It was undertaken in order to render assistance to the German Federal Republic (West Germany) in the proposed codification of its chemical food preservatives laws.[b] Until such laws become available, all official declarations permitting the use of any preservative rest on directives based on a 1933 draft of a chemical food preservative law which was never passed. Food technologists and the industries concerned are endeavoring to submit for consideration by the West German legislature a new draft, in which the viewpoints of the effect on health, the efficacy and specificity of the preservatives to be permitted are fully taken into account.

Of the preservatives included in this paper the following are allowed and actually used for the commercial preservation of foodstuffs: Benzoic acid and its sodium salt, sulfuric acid and sulfites, p-chlorobenzoic acid and its sodium salt, esters of p-hydroxybenzoic acid, formic acid, propionic acid and propionates. It is the general consensus that the new code will allow the use of these preservatives for certain foodstuffs. At the time of writing boric acid is still allowed and in use for the preservation of a very few foodstuffs, such as crabs, anchovy and liquid yolk. It seems doubtful whether boric acid will be allowed in the future; for theoretical reasons it was included in the experiments. Salicylic acid, also included in this review, is at present not allowed in Germany for commercial preservation of foodstuffs. It is used in German households and, on occasion, also for the impregnation of cover paper for jams. Dehydroacetic acid and its salts have also not yet been allowed in Germany. They were included in the investigations on account of their scientific interest *(16)*.

It should be emphasized that these investigations concern only the efficacy of the preservatives in inhibiting microbial spoilage of foodstuffs. Neither their harmful effects on health nor their general effect on the human organism was included in the objective. All experiments herein described, however, made a minimum use of such substances in consideration of the fact that their use cannot be avoided entirely. The principal aim was to learn the specificity of the preservatives so that from among the large number of possible preparations the most efficacious one may be selected. This will make possible the elimination from consideration of substances which are ineffective under the given conditions.

II. Mechanism of microbial inhibition by chemical preservatives. Preservatives can react with cell membranes, thereby increasing their permeability which admits cellular toxins and permits cellular contents to escape. Preservatives can also destroy or inactivate indispensable enzymes. Particulars about these interesting but not wholly solved problems can not be given here. The literature on this aspect of the question has been reviewed by Wyss *(11)*.

The reversibility or irreversibility of the cell-reacting activity of the preservative determines whether the action is bacteriostatic (fungistatic) or lethal. In most instances both processes blend into each other and it depends on the concentration whether the action is inhibitive or lethal; in some instances it may be that the cell is destroyed indirectly through lack of substances necessary for its metabolism.

III. Relation between the reaction of the substrate-preservative system and the efficacy of preservatives. Numerous investigators (Cruess and co-workers *(12, 13)*, Rahn and Conn *(14)* and others) have shown, that in preservatives embodying monobasic weak acids or their salts, only the undissociated fraction is active against microorganisms.

This rule of the microbiological efficacy being in direct ratio to the undissociated fraction of preservatives having the character of salts or acids does not apply to the neutral range as already noticed by Vernast *(15)* in 1929. The writer's own investigations confirmed that, although the minimum effective concentration of preservatives possessing the character of salts or acids increases with increasing pH-value, this concentration is nevertheless considerably lower than its theoretical value for reactions within the neutral pH-range (see Tables 1, 2, 3).

Sulfurous acid is known to have 2 dissociation stages besides the undissociated form. Undissociated H_2SO_3 and the HSO_3' ions are microbiologically active, the first considerably more so than the latter *(5)*.

The esters belong to the type of undissociated preservatives. The ester concentration required for a proper preserving efficacy

TABLE 1

Theoretical and experimentally established concentration (mg. per 100 ml.) of sodium benzoate and ethyl ester of p-hydroxybenzoic acid required for inhibiting reproduction of Saccharomyces cerevisiae in concentrations of 2.5×10^6 cells per ml.

	pH value of substrate preservative system						
	2	2.6	3	4	5	6	7
Theoretical concentration of sodium benzoate	26	27	28	43	200	1,730	17,300
Experimental concentration of sodium benzoate		20			200		3,000
Experimental concentration of ethyl ester of p-hydroxybenzoic acid		80			80		100

TABLE 2

Theoretical and experimentally established concentrations (mg. per 100 ml.) of sodium benzoate and ethyl ester of p-hydroxybenzoic acid required for inhibiting reproduction of Willia anomala in concentrations of 2.5×10^6 cells per ml.

	pH value of substrate preservative system						
	2	2.6	3	4	5	6	7
Theoretical concentration of sodium benzoate	13	13	14	22	100	865	8,650
Experimental concentration of sodium benzoate		12			100		2,000
Experimental concentration of ethyl ester of p-hydroxybenzoic acid		60			60		80

[a] Report from Institut fur Lebensmitteltechnologie, Munchen, Germany; Director, Dr. Ing. habil. Rudolf Heiss.

[b] The German Democratic Republic (East Germany) has already promulgated its chemical food preservatives law.

TABLE 3

Theoretical and experimentally established concentrations (mg. per 100 ml.) of sodium benzoate and ethyl ester of p-hydroxybenzoic acid required for inhibiting reproduction of Penicillium glaucum in concentrations of 2.5×10^5 spores per ml.

	pH value of substrate preservative system						
	2	2.6	3	4	5	6	7
Theoretical concentration of sodium benzoate	52	53	55	87	400	3,500	35,000
Experimental concentration of sodium benzoate		60			400		6,000
Experimental concentration of ethyl ester of p-hydroxybenzoic acid		60			60		80

does not increase in the same degree with the pH-value of the substrate-preservative system as with preservatives having the character of salts or acids. The writer's investigations into the activity of p-hydroxybenzoic esters showed nevertheless that for a certain preservative action somewhat lesser amounts of esters suffice for acid reaction than for neutral reaction. (Tables 1, 2, and 3 are also illustrative of this fact.)

Tables 1, 2, and 3 show the experimentally determined amount of sodium benzoate and ethyl ester of p-hydroxybenzoic acid required for inhibiting the reproduction of 2.5×10^5 cells or spores per ml. of several microorganisms at different pH-values. The test procedure is described in detail in Section IV. A slight idea of the process is, however, necessary to understand the tables: The preservative in question is added to malt broth and the solution adapted to the desired pH-value by adding hydrochloric acid.

Tables 1 to 3 give also the theoretic value of the amount of sodium benzoate required at different pH-values. It is arrived at in the following way: At every pH-value of the substrate-preservative system there results a certain amount of undissociated benzoic acid for a certain amount of sodium benzoate used. According to the authors previously cited and the writer's investigations, a fixed amount of undissociated benzoic acid is required to achieve a certain microbiological action. It is therefore possible—after finding experimentally the amount of sodium benzoate required to achieve a certain preservative effect at a certain pH-value of the substrate-preservative system—to compute theoretically the amount of sodium benzoate required for the same preservative effect at some other pH value of the substrate-preservative system. All values of the theoretical concentration of sodium benzoate listed in Tables 1, 2, and 3 are based on the amount of sodium benzoate required at pH 5. This amount is determined by experiment.

It was found, for instance, that 200 mg. of sodium benzoate are required for 100 ml. of the substrate-preservative system at pH 5 to inhibit the reproduction of *Saccharomyces cerevisiae* present at a concentration of 2.5×10^5 cells per ml. This corresponds to 22 mg. of undissociated benzoic acid. In order to have 22 mg. of undissociated benzoic acid present at pH 2.0 of the substrate-preservative system 26 mg. of sodium benzoate are required, at pH 2.6, 27 mg., at pH 7 even 17,300 mg.

Table 4 shows the results of experiments made to determine the amount of sodium salt of dehydroacetic acid required for inhibiting the reproduction of different test microbes present in concentrations of 2.5×10^5 cells or spores per ml.

TABLE 4

Concentration of sodium salt of dehydroacetic acid (mg. per 100 ml.) required for inhibiting reproduction of 2.5×10^5 cells or spores/ml. at different pH-values of the substrate-preservative system

pH value	Concentration (mg./100 ml.) required for inhibiting		
	Willia anomala	*Penicillium glaucum*	*Aspergillus niger*
3.5	5	7	5
5	15	20	20
7	1,000	500	500

Toxicity of dehydroacetic acid and its salts is shown to be related to the pH-value. The opinion expressed by Wolf and Westveer (*15*), that dehydroacetic acid shows a behavior in this respect different from that of the other acids, was not confirmed.

IV. Determination of the absolute efficacy of preservatives. The absolute efficacy of any preservative can only be determined after due consideration of the relation between dissociation and effective fraction discussed in the preceding section. For such determinations it is, therefore, necessary to precisely adjust or determine the initial pH-value of the substrate-preservative system. In evaluating the results all pH changes caused by metabolic reactions of some microorganisms, such as *Saccharomyces cerevisiae* or *Escherichia coli* have to be taken into account.

The results of some earlier work deficient in this respect must therefore be accepted with some reservations.

The writer developed the following procedure for determining the absolute efficacy of a preservative:

The substrate composed of 50 g. malt extract, 10 g. dextrose, 5 g. peptone, 3 g. Liebig's meat extract, 1000 ml. distilled water, permits not only growth and reproduction to yeasts and moulds but also to *Escherichia coli* and *Bacillus subtilis*. The same substrate can therefore be used to observe the efficacy of preservatives against moulds and yeasts, as well as bacteria.

The preservative is added in amounts increased by one quarter or one third in each successive test. The mixture is adjusted to the desired pH value by adding either sodium hydroxide or hydrochloric acid. Buffers are not added in order to avoid any change in the osmotic values since such changes may have an influence on the activity of the preservatives. Any pH changes during the test—an important evidence of life and reproduction in the inoculum—can also be detected more readily in the absence of any buffer substance. The test samples filled in test tubes are sterilized prior to their inoculation. In case the preservatives are volatile substances—such as sulfurous acid, propionic acid, formic acid—the test tubes are a, sealed by fusing prior to sterilization, b, sterilized, c, cooled off for 24 hours accompanied by frequent shaking, d, opened, e, quickly inoculated and, f, resealed.

With yeasts and moulds 2.5×10^6 cells or spores/ml. were used for inoculation; with bacteria, 5×10^6/ml. Tests were evaluated after a 6 days' incubation at 20° C. for yeasts and moulds, after 4 days' incubation at 37° C. for *Bacillus subtilis* and 24 hours at 37° C. for *Escherichia coli*. Reproduction was ascertained macroscopically and also detected by checking the pH-value. A decided reduction of the pH-value below a certain minimum caused by the metabolism of the inoculum showed that the inoculum had reproduced itself. In tests in which the pH-value had dropped off considerably the food was evaluated as 'spoiled,' and the concentration of preservative regarded as insufficient. All tests were repeated several times.

This test procedure permits an exact definition of the concentration of preservative required for the inhibition of the inoculum. From the constant pH-value of the substrate-preservative system and the dissociation constant of the preserving acid in question it was possible to determine theoretically the point of absolute efficacy and to make comparisons between them in this respect. As elaborated in the following sections, the absolute efficacy of the several preservatives depends on the species (and even subspecies) of the microbes serving as test objects. In Table 5, a compilation of the results of the writer's own investigations, the microbial efficacy of some acids is compared with that of undissociated

benzoic acid. These values are averages of different tests made at pH values between 4.5 and 6. In the neutral range (pH = 7) the situation is somewhat different (see pages 97, 98) and it must be admitted that full insight has not yet been gained.

TABLE 5

The values given are gr./100 ml. of the effective component of a preservative having the same toxicity on the different species of microbes as 1 g. of undissociated benzoic acid

Effective component	*Saccharomyces cerevisiae*	*Pichia membranae faciens*	*Penicillium glaucum*	*Escherichia coli*
Undissociated benzoic acid	1	1	1	1
Undissociated salicylic acid	0.1	0.1	0.3	0.03
Undissociated p-chlorobenzoic acid	0.8	0.6	1	0.7
p-hydroxybenzoic ethylester	4	3	2	8
HSO_3^-	9	10	3	0.9
Undissociated propionic acid	13	13	5	8
Undissociated formic acid	2	4	15	0.3
Undissociated dehydroacetic acid	3		0.2	8
Undissociated dehydroacetic acid	*Bac. subt.* 8	*Asp. niger* 0.2	*Hefe anomala* 1	

Of all the acids listed in Table 5, salicylic acid, p-chlorobenzoic acid and, for some species of bacteria, dehydroacetic acid have been found to have a high absolute efficacy; all others have a low absolute efficacy. The specificity of these acids is discussed in a later section.

Undissociated sulfurous acid has not been included in Table 5, since its action, for various reasons, could not be determined as exactly as that of other preservatives. The determination of the absolute efficacy of HSO_3^-ions and of undissociated sulfurous acid was the object of a separate paper *(5)* by the writer. It showed undissociated sulfurous acid to be a more efficient preservative than all the other substances listed in Table 5. Undissociated sulfurous acid was found to be about 100 to 500 times as efficient against all microorganisms tested as undissociated benzoic acid.

The following example shows in which way the absolute efficacy of undissociated sulfurous acid may be determined. In order to eliminate any discrepancies owing to the high volatility of free SO_2, all experiments are made at comparatively high pH-values.

At pH 6 (adjusted after adding the preservative) the reproduction of 2.5 10^6 cells/ml. of *Saccharomyces cerevisiae* is inhibited by

1750 mg./100 ml. of Na_2SO_3 or 1750 mg./100 ml. of sodium benzoate.

Both amounts therefore have the same effect. After dissociation at pH 6 there are present the following microbiologically active fractions:

When 1750 mg./100 ml. of Na_2SO_3 is added:
195 mg. HSO_3^- and 1×10^{-7} mg. of undissociated H_2SO_3.

When 1750 mg. of sodium benzoate is added per 100 ml.:
22.5 mg. of undissociated benzoic acid.

Therefore, 195 mg. of HSO_3^- is shown to have the same effect on *Saccharomyces cerevisiae* as 22.5 mg. of undissociated benzoic acid.

Thus:

(1) 1 mg. of HSO_3^- has the same effect as 0.12 mg. of undissociated benzoic acid

At pH 4.5 the reproduction of 2.5 $\times$ 10^6 cells/ml. of *Saccharomyces cerevisiae* is inhibited by 200 mg./100 ml. of Na_2SO_3 or 200 mg./100 ml. of sodium benzoate.

(The identical figures for the required concentration are only a coincidence. For other microbes the values differ.)

After dissociation at pH 4.5 the following microbiologically active fractions are present:

When 200 mg. of Na_2SO_3 is added per 100 ml.:
114 mg. of HSO_3^- and 0.2 mg. of H_2SO_3.

When 200 mg. of sodium benzoate is added per 100 ml.:
55 mg. of undissociated benzoic acid.

From (1) there follows:

114 $\times$ 0.12 mg. = 13.7 mg. of undissociated benzoic acid + 0.2 mg. of H_2SO_3 has the same effect as 55 mg. of undissociated benzoic acid.

Therefore:

0.2 mg. of H_2SO_3 has the same effect as 41.3 mg. of undissociated benzoic acid,

or:

1 mg. of H_2SO_3 has the same effect upon *Saccharomyces cerevisiae* as 206 mg. of undissociated benzoic acid.

V. Contribution of both factors "amount of microbiologically active efficient fraction" and "absolute efficacy." The practical efficacy of preservatives at a certain pH-value of the substrate-preservative system is dependent on the magnitude of the microbiologically active efficient fraction and the absolute efficacy (for exceptions at neutral pH-values see pages 97, 98).

Undissociated sulfurous acid as well as salicylic acid are preservatives with a high absolute efficacy. But they have a strong tendency towards dissociation. Therefore, their compounds are only usable for the preservation of foodstuffs with acid reaction or after adding acidifying substances. If the substrate-preservative system reacts only slightly acid or neutral, both these preservatives become ineffective notwithstanding their high absolute efficacy. The reason is that the undissociated fraction becomes too small.

Formates, benzoates and salts of p-chlorobenzoic acid are also unsuitable within the low acid to neutral range. Although their tendency towards dissociation is less marked than with sulfurous and salicylic acid, their lower absolute efficacy forces the use of too high an amount to make their use feasible in cases of low acid to neutral reaction of the substrate-preservative system.

The absolute efficacy of p-hydroxybenzoic esters leaves something to be desired. Since they do not tend to dissociate even in the neutral pH range, however, they are to be preferred to the afore-mentioned preservatives for such foodstuffs.

Propionic acid is a preservative of rather low absolute efficacy. As the tendency towards dissociation is also low, the acid remains somewhat effective also within the low acid range. Its salts can therefore be used, for instance, for the impregnation of wrappings for low acid foodstuffs. Of all the compounds so far examined, it seems that dehydroacetic acid and its salts come closest to the desired aim of being effective also in an approximately neutral pH state, since they combine fair absolute efficacy (but only against moulds) with low dissociation. Investigations have shown that boric acid also has a low absolute efficacy, and that only its very weak tendency

towards dissociation accounts for its relatively satisfactory efficacy within the neutral to slightly alkaline range.

VI. Specificity of preservatives against microorganisms. In the literature frequent reference is made to the specificity of certain preservatives towards species or sub-species of microorganisms. The statements are sometimes rather contradictory. At least part of them seem to rest on experiments made without checking pH values, which means that no account has been taken of the ensuing change in efficiency of the preservative.

From the writer's own observations, which were made under strict observance of this interrelation, the following conclusions can be drawn (cf. Table 5):

Propionic acid and dehydroacetic acid are evidently highly specific against moulds. Therefore compounds of both can be used very successfully to combat moulds.

The p-hydroxybenzoic esters as well as HSO_3' ions are also comparatively more specific against moulds than against yeasts.

Of striking interest is the rather poor activity of dehydroacetic acid against bacteria *(16)*. (This has also been noted and reported by industrial laboratories.) On the other hand, formic acid and salicylic acid are evidently quite specific against bacteria.

Rahn and Conn *(14)* mention that HSO_3' ions are specific against *Escherichia coli*, but not against *Saccharomyces cerevisiae*. Nevertheless, it cannot be denied that HSO_3' ions are not less active than other recognized preservatives in their toxicity to *Saccharomyces cerevisiae* and other yeasts and fungi.

A full insight into the reasons for the specificity of different preservatives against the several species of microbes can only be obtained through a thorough study of their metabolism. This applies also to the problems discussed in the next section, the susceptibility of microorganisms to preservatives. Numerous and intricate problems are still awaiting solution.

VII. Susceptibility of different microorganisms to the action of preservatives. Table 6 furnishes a comparison of the efficacy of different preservatives with that of undissociated benzoic acid. Of course, Table 5 does not imply that an equal amount of undissociated benzoic acid is required for the inhibition of the reproduction of the same number of cells or spores of all species of microbes in question. Table 6 shows that quite different amounts of benzoic acid and likewise other preservatives are required to inhibit 2.5×10^6 spores or cells per ml. of the different species mentioned.

TABLE 6

Concentration of sodium benzoate (at pH 5) and equivalent fraction of undissociated benzoic acid required for the inhibition of reproduction of 2.5×10^6 cells or spores/ml. of different microbes

Microbe species	Required concentration of	
	Sodium benzoate	Undissociated benzoic acid
	mg./100 ml.	*mg./100 ml.*
Saccharomyces cerevisiae	200	22
Willia anomala	100	11
Pichia membranaefaciens	300	33
Penicillium glaucum	400	44
Aspergillus niger	300	33

Table 7 shows to what extent the resistance of the different varieties of one microorganism to one and the same preservative varies. This table shows the resistance of different forms of *Saccharomyces cerevisiae* to benzoic acid. The comparison was extended to commercial bakers' yeast, brewers' yeast and to a one-cell culture isolated from brewers' yeast.

TABLE 7

Concentrations of sodium benzoate (at pH 4.5) and undissociated benzoic acid required for the inhibition of the reproduction of 2.5×10^6 cells/ml. of different forms of Saccharomyces cerevisiae

Form	Concentration of	
	Sodium benzoate	Undissociated benzoic acid
	mg./100 ml.	*mg./100 ml.*
Commercial bakers' yeast	50	13
Commercial brewers' yeast	200	54
One-cell culture	150	40

So far the resistivity of only very few species of microorganisms has been studied. We do not know which species are most resistant to preservatives in general and to individual compounds in particular when present in foodstuffs. This is one reason why the minimum concentration of preservatives cannot be predicted theoretically for any individual product.

The resistivity of a microbe is also dependent to a great extent on the age and health of the culture used in the experiment. The values of Table 6 can, therefore, not be regarded as infallible. Table 6 will serve in the first line to demonstrate the fact that great variations exist in the resistivity of the different species.

VIII. Combination of preservatives. In discussions relating to the establishment of new laws concerning food preservation in the West German Federation, frequent mention was made of the problem whether a combination of preservatives presents advantages. The German canning industry favors this method and several combinations of 2 or more preservatives, some also including other additions, are on the market.

There is no doubt that the use of combinations of preservatives may possess some advantages over that of the unmixed substances. Especially as regards flavor, combinations of 2 preservatives will be more favorable, provided smaller amounts of each are required in the combination. Some preservatives do not dissolve readily, so that only inadequate amounts of them can be added. In these cases the complementary action of a second preservative can be very valuable.

The German canning industry is also of the opinion that the several component preservatives may have cumulative effects, thus enabling the toxic substances to be more sparingly used; but they are unable to give an explanation of this supposition. In search of an explanation the Institut für Lebensmitteltechnologie, München, examined several combinations of preservatives to seek evidence of a cumulative effect. Many instances were found where the simultaneous use of several preservatives in lieu of one substance only constitutes an increased consumption and increased addition of chemical matter, as exemplified by the combination

benzoate plus formate *(1)*. There were other instances where the effect of the combination is simply the added effect of the *2* components, evidenced by the combination of benzoic acid or benzoate respectively with parahydroxybenzoic esters *(4)*. There are also combinations of preservatives which allow a reduction in toxic matter by choosing the partners suitably *(7)*. Three possibilities have been recognized:

1. Combinations of preservatives may have a higher efficacy than the sum of the components when one component, a free acid, increases the microbiologically active fraction of the other component. This is true for the combination of benzoic acid or benzoate with formic acid infrequently used in Germany. A similar effect can also be achieved by the combination with compounds which have no preservative but only an acidifying action *(7)*.

2. In some cases less of the toxic substance may be required when employing a combination of *2* or more preservatives, since the components will have a different toxicity to the different species of microorganisms (and the foodstuffs will be prone to attack by different species). So far only few really practical examples have been found for this possibility. The study of the specificity of preservatives will doubtlessly increase the number of applications.

3. In some cases it was found that a combination of *2* preservatives was more efficacious against cells of one and the same microbe species than could be expected from the sum of the toxicity of both components, even when taking dissociation into account and when no mutual chemical influence between the dissociation products of the components was present. An example of this kind has been described in the combination benzoate + sulfite *(7)*. The reason for this unproportional increase in efficacy is not yet known.

IX. Further factors influencing the efficiency of chemical food preservatives. Besides the factors already discussed, there are a score of other factors which influence the efficacy of chemical food preservatives. The following examples are worthy of mention:

SO_2 *(17, 18, 19)* forms reaction products with sugars and aldehydes. Substrates rich in glucose inhibit a considerable fraction of the added sulfurous acid.

Foodstuffs with high sodium chloride content need, on account of their high osmotic value, lower concentrations of preservatives than foodstuffs richer in water *(6)*.

Other instances will be found where the nature of foodstuffs or their components influences the efficacy of preservatives. The fact that not all of these influencing factors have been found, is another of the reasons why our present theory is not quite adequate to predict, in every instance, the required minimum concentration of preservative. As soon as all basic factors are known we shall be able to understand any and every application.

CONCLUSION

The efficacy of preservatives added to foodstuffs to prevent spoilage through microbial activity is mainly dependent on two factors; namely on the amount of the undissociated fraction of the preservative and on its absolute efficacy. The latter is different against different species of microorganisms.

Of high absolute efficacy against all microorganisms so far examined are undissociated sulfurous and salicylic acid. Their use is restricted to the acid pH-range on account of their strong tendency towards dissociation. Also only applicable in the strong acid pH-range are formic, benzoic, and p-chlorobenzoic acid which have a less marked tendency to dissociate but also a lower absolute efficacy. For low acid reaction of the substrate-preservative system, dehydroacetic acid can be used, which shows a high absolute efficacy, at least against moulds. Quite independent of the pH-value is the efficacy of preservatives composed of esters. Although the absolute efficacy of p-hydroxybenzoic esters is lower than that of benzoic acid, they are nevertheless superior to benzoic acid and its salts as well as to other preservatives of acid or salt character for low acid or neutral reaction of the substrate-preservative system.

The toxicity of preservatives can vary greatly with varieties of one and the same species. Still greater variations obtain for the different species.

Combinations of several preservatives can constitute an economy under certain conditions.

The present experimental results may serve as a basis for the comprehension of the efficacy and applicability of preservatives, but they still do not per mit the prediction of concentrations required in commercial cases for the preservation of any and every foodstuff.

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Effect of Preservatives on Fermentation Spoilage in Pickled Cherries[a]

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(Manuscript received March 8, 1952)

A report is given on studies of the relative preservative effect of various concentrations and combinations of acetic acid, sodium chloride, sucrose and sodium benzoate on the growth of selected yeasts, including an acid tolerant strain isolated from pickled cherries. Information is presented indicating the conditions required for prevention of spoilage by yeasts.

Pickled cherries, or "cherry olives" as commonly termed in British Columbia, have for many years been prepared by housewives. The home product is variable in keeping quality. In 1949 a small commercial pack was produced in British Columbia, based on what was considered to be the best home formula. This formula of vinegar, sugar, and salt normally gave a concentration in the finished product of approximately 1.8% acid, calculated as acetic, 1.5% sodium chloride and 20% sugar. These are concentrations which are often considered to be satisfactory for preservation of pickled foods. Under home conditions no spoilage had been encountered in unpasteurized samples processed according to this formula. However, a number of samples of the commercial product showed considerable yeast fermentation, even in the presence of 0.03% sodium benzoate.

Investigations *(2, 5, 6, 8, 9, 10)* have shown that acetic acid and sodium benzoate are the most effective preservatives. Sugar and salt, in concentrations which yield an acceptable product, are of less importance. Tanner and Strauch *(13)* found that certain species of yeast were more resistant than others to sodium benzoate.

Heath *(7)* indicates that 2 to 2.5% acetic acid is necessary to prevent growth of most spoilage organisms in sauces, pickles and relishes, and suggests that best results are obtained by combinations of 1.5% acetic acid, 1.5% sodium chloride and 30% sucrose. Burrell *(1)* and Poultney *(11)* recommend a minimum concentration of 3.6% acetic acid in order to guarantee preservation of pickles. Mention is made by Poultney *(11)* of fermentation due to the presence of acid resistant bacteria occurring in a product containing 4% acetic acid.

Limited tests of the fermented samples of "cherry olives" indicated that the yeast responsible for spoilage was tolerant to high concentrations of acetic acid, and perhaps also to sodium benzoate. In view of the possible commercial development of this product, it was considered desirable to study the nature of the spoilage organism present in the cherry samples together with methods of control. A number of yeast species which might be encountered in such a product were included in the investigation.

EXPERIMENTAL PROCEDURE

A sample of commercially packed "cherry olives" showing evidence of yeast fermentation was examined chemically and bacteriologically. The product consisted of sweet cherries preserved in vinegar, salt, sugar and sodium benzoate. Chemical analysis indicated a pH value of 3.5, total titratable acidity of 1.25%, calculated as acetic acid, 1.5% sodium chloride, 15% sugar and 0.03% sodium benzoate. The yeast responsible for fermentation was isolated and identified as being of the genus *Zygosaccharomyces*. In order to determine the resistance of this strain to various preservatives, the effect of different combinations of acetic acid, sodium chloride, sugar and sodium benzoate was studied. For comparison, tests were undertaken using the following type cultures: *Saccharomyces cerevisiae, Endomyces vernalis, Schizosaccharomyces pombé, Candida krusei, Hansenula suaveolens, Torulopsis utilis* and *Saccharomyces ellipsoideus*.

Apple juice, to which was added the various combinations of acetic acid, sucrose and sodium chloride, served as the basal medium, since cherry juice unfortunately was not available at the time. Allowance was made for the total sugar content and the titratable acidity of the apple juice, usually about 13% and 0.2% respectively, in calculating the amounts of sugar and acid to be added.

One drop of an active 24-hour peptone glucose broth culture was inoculated into each tube of the apple juice medium. Production of gas, demonstrated by the agar plug method, was taken as evidence of growth. To make this method semi-quantitative, a value of +1 was given for each 15 mm. of gas, as indicated by the raising of the plug in the culture tube. Agar was used only in the initial experiments, petroleum jelly being substituted thereafter since it gave more consistent results. Each series of tests was replicated 5 times.

Resistance to pasteurization of *Zygosaccharomyces sp.* isolated from "cherry olives" was also studied. One drop of a 24-hour peptone glucose broth culture of the yeast was added to each of several tubes of peptone glucose broth. Duplicate tubes were held in the water bath for 10 minutes at each temperature selected. Five degree intervals were used over the range 45°-90° C. (113°-194° F.). The cultures were cooled immediately after heating, plated on peptone glucose agar and incubated at 28° C. Absence of growth indicated destruction of the yeast by the heat treatment.

EXPERIMENTAL RESULTS

In presenting the results of this investigation, tabular data are given only for the organisms showing the greatest degree of resistance to the various treatments.

Effect of acetic acid, sugar and sodium chloride on yeast growth. Table 1 presents data on the separate effects of acid, sugar or salt on growth of the yeast species under investigation.

The yeasts tested showed a variable degree of resistance to acetic acid. *Zygosaccharomyces sp.* is the most resistant, growing in 4% acid solution. *Schizosaccharomyces pombé* is next in order of acid tolerance, producing gas in 3% acid. *Endomyces*

[a]Contribution No. 334 (Journal Series) from Division of Bacteriology and Dairy Research, Science Service and No. 777 Horticultural Division, Experimental Farms Service, Canada Department of Agriculture. Issued as Paper No. 280 of the Canadian Committee of Food Preservation.

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TABLE 1
Effect of acetic acid, sugar and sodium chloride on yeast growth

Treatment				Yeasts			
Acid %	Sugar %	Salt %	pH	*Zygosaccharomyces sp.*	*Saccharomyces cerevisiae*	*Endomyces vernalis*	*Schizosaccharomyces pombé*
1.5			3.4	++++	++++	++++	++++
2.0			3.3	++++	—	+	++++
2.5			3.2	++++	—	—	++
3.0			3.1	+++	—	—	+
4.0			3.0	++	—	—	—
	30		3.8	++++	++++	++++	++++
	40		3.8	++	++++	++++	++++
	50		3.8	++	++++	++++	++++
	60		3.8	++	++++	+++	+++
		5	3.8	++++	++++	++++	++++
		10	3.8	+++	+++	+	++
		15	3.8	+	—	—	+

vernalis is inhibited by acetic acid in concentrations greater than 2%. *Saccharomyces cerevisiae* is able to grow in 1.5% acid but not in 2%. *Saccharomyces ellipsoideus* and *Candida krusei* are able to grow in 1% but not in 2% acid. *Hansenula suavolens* and *Torulopsis utilis* are unable to grow in 1% acid concentration.

The yeasts tested, with the exception of *Torulopsis utilis* and *Candida krusei*, are able to grow and produce gas in sugar concentrations up to 60%. *Torulopsis utilis* grew in 50% but not in 60%, while *Candida krusei* grew in 40% but not in 50% sucrose-apple juice mixture.

At 15% concentration sodium chloride exerts a marked inhibiting effect on *Zygosaccharomyces sp.* and *Schizosaccharomyces pombé*, and prevents growth of *Saccharomyces cerevisiae* and *Endomyces vernalis*. *Candida krusei*, *Hansenula suavolens*, and *Saccharomyces ellipsoideus* were not able to grow in concentrations of salt greater than 5%, while *Torulopsis utilis* failed to grow in a 1% salt-apple juice mixture.

These data indicate that of the acid, sugar and salt components, acetic acid is the most effective in checking yeast growth. Sodium chloride and sugar by themselves are not effective as preservatives except in concentrations which would render the product unpalatable.

Effect of combination of two ingredients on yeast growth. Table 2 presents data on the effect of the following combinations of two ingredients on yeast growth: acid and sugar; acid and salt; sugar and salt.

The addition of 30% of sucrose to the acidified apple juice medium had no appreciable effect on the growth of the yeasts tested. With the exception of *Saccharomyces cerevisiae*, which showed reduced production of gas in 1% acid with 30% sucrose, the selected yeasts were not inhibited by the increased sugar concentration in the presence of acetic acid.

Sodium chloride combined with acetic acid is somewhat more effective than acid alone in checking the growth of yeasts. In the case of *Zygosaccharomyces sp.* and *Schizosaccharomyces pombé*, growth is inhibited at a lower acid concentration where 2% sodium chloride is present than in a solution containing acid alone. Increasing the salt content to 4% intensified the inhibiting effect. However, *Zygosaccharomyces sp.* was most resistant of all the yeasts tested, still growing slowly at 3% acid and 4% salt. *Saccharomyces cerevisiae* and *Endomyces vernalis* show reduced growth in the 1% acid solution containing 4% salt, whereas in apple juice with 1.5% acid alone (Table 1) they show vigorous growth and production of gas. In the case of *Candida krusei* growth was checked completely in acid solutions greater than 1% both with and without added salt. *Saccharomyces ellipsoideus*, which grew vigorously in 1% acid solution without salt, showed reduced gas production when 2% salt was added, and was completely checked at the 4% salt level.

Sodium chloride and sugar combined in the apple juice medium appear to have a greater inhibiting effect against the yeasts tested than either ingredient added separately. *Zygosaccharomyces sp.* showed reduced growth in 15% and 30% sugar solution where 3% or more of salt was present. Growth, however, was not prevented in any of the concentrations used. *Schizosaccharomyces pombé* appears to be even more resistant, showing fairly vigorous growth in 15% and 30% sugar solutions containing up to 10% of salt. *Saccharomyces cerevisiae* and *Endomyces vernalis* show reduced growth in 30% sugar with 5% salt and are completely checked in 15% sugar with 10% salt. *Candida krusei* and *Saccharomyces ellipsoideus* were found to be completely inhibited in the sucrose solutions containing 5% of salt, whereas they showed slight growth at this salt concentration where no sugar was added, and were able to grow vigorously in salt-free sugar solutions containing up to 40% of sugar.

TABLE 2
Effect of combinations of two ingredients on yeast growth

Treatment				Yeasts			
Acid %	Sugar %	Salt %	pH	*Zygosaccharomyces sp.*	*Saccharomyces cerevisiae*	*Endomyces vernalis*	*Schizosaccharomyces pombé*
1	30		3.5	++++	+	++++	++++
2	30		3.3	++++	—	++	++++
3	30		3.2	++++	—	—	+++
4	30		3.1	++	—	—	—
1		2	3.5	++++	++++	++++	++++
1		4	3.5	++++	++	+	++++
2		2	3.3	++	—	—	+++
2		4	3.3	+	—	—	+
3		2	3.15	+	—	—	—
3		4	3.15	+	—	—	—
	15	1	3.8	++++	++++	++++	++++
	30	1	3.8	++++	++++	+++	+++
	15	3	3.8	+++	++++	++++	++++
	30	3	3.8	+++	+++	+++	+++
	15	5	3.8	++	++	++	+++
	30	5	3.8	++	++	+	+++
	15	10	3.8	+	—	—	++
	30	10	3.8	+	—	—	++

Effect of combined acetic acid, sodium chloride and sugar. Combinations of acetic acid, sodium chloride and sugar, in concentrations which would give satisfactory condition and palatability in "cherry olives" (12), do not check the growth of *Zygosaccharomyces sp.* (Table 3). The maximum amounts used are 2.5% acetic acid, 2% salt and 35% sugar. *Schizosaccharomyces pombé* grows vigorously in the solution containing 1.5% acid, 2% salt and 25% sugar. Growth is reduced when the sugar concentration is raised to 35% and when the acid is increased to 2%. It is unable to grow when the acid concentration in the mixture reaches 2.5%. *Saccharomyces cerevisiae* grows only weakly in the lowest range of acid, sugar and salt, and is com-

TABLE 3
Effect of combined acetic acid, sugar, sodium chloride and sodium benzoate on yeast growth

Treatment				Yeasts					
				Zygosaccharomyces sp.		*Saccharomyces cerevisiae*		*Schizosaccharomyces pombé*	
Acid %	Sugar %	Salt %	pH	No Benzoate	0.1% Benzoate	No Benzoate	0.1% Benzoate	No Benzoate	0.1% Benzoate
1.5	25	2.0	3.4	++++	+++	+	—	++++	—
1.5	35	2.0	3.4	++++	++++	—	—	++	—
2.0	30	2.0	3.3	++++	—	—	—	++	—
2.5	25	2.0	3.1	++++	—	—	—	—	—
2.5	35	2.0	3.1	++++	—	—	—	—	—

pletely inhibited by the higher concentrations. *Saccharomyces ellipsoideus* grows vigorously in the mixture of 1.5% acid, 2% salt and 25% sugar. It shows reduced growth when the sugar concentration is raised to 35%, and fails to grow when the acid concentration reaches 2%. *Endomyces vernalis, Candida krusei, Hansenula suavolens* and *Torulopsis utilis* were found to be unable to grow in any of the combinations of acid, sugar, and salt used.

Effect of sodium benzoate on yeast growth. Sodium benzoate in 0.1% concentration prevents growth of all yeasts tested with the exception of *Zygosaccharomyces sp.* (Table 3) and *Saccharomyces ellipsoideus*. *Zygosaccharomyces sp.* is able to produce gas in 1.5% acetic acid solutions containing 2% salt, 35% sugar and 0.1% sodium benzoate, but is unable to grow in these mixtures when the acid concentration is increased to 2%. However, other experiments showed that in the absence of sugar and salt this organism grew in solutions containing 0.1% benzoate and 2% acid but not when the acid concentration was increased to 3%. Thus the combination of sugar and salt contributed to the inhibitory effectiveness of the mixtures at the levels used. However, increasing the acidity of the solutions with acetic acid was the dominant factor in intensifying the effect of the benzoate.

In salt solutions containing up to 5% sodium chloride, *Zygosaccharomyces sp.* was able to grow in the presence of 0.1% sodium benzoate. Above 5% concentration, sodium chloride increased the inhibitory action of the benzoate.

In solutions containing sugar alone in concentrations up to 35%, the effect of 0.1% sodium benzoate was not altered by the presence of sugar.

Experiments showed *Saccharomyces ellipsoideus* to be able to grow in unacidified apple juice containing 0.1% sodium benzoate, but to be prevented from growing in a solution containing 1.5% acetic acid.

Effect of pasteurization on yeast isolated from "cherry olives." The amounts of acetic acid, sodium chloride and sugar (2%, 2% and 30% respectively), which normally should be present in pickled cherries *(12)*, are sufficient to prevent fermentation by most yeasts. However, unless the product is to be pasteurized, the addition of 0.1% sodium benzoate is also necessary to control resistant yeasts such as *Zygosaccharomyces sp.*, discussed in this work.

Tests of the heat resistance of *Zygosaccharomyces sp.* showed that it was destroyed by heating to 60° C. (140° F.) for 10 minutes. It would appear, therefore, that pasteurization of "cherry olives" at this temperature would be a satisfactory means of preventing spoilage in this product by acid resistant yeasts. However, pasteurization results in a much less attractive product, since it reduces color and brightness, causes severe checking, and in extreme cases, splitting of the fruit.

DISCUSSION

The species of yeasts tested show a wide range of acid tolerance, from extreme sensitivity, shown by *Torulopsis utilis* and *Hansenula suavolens*, to extreme resistance, demonstrated by *Zygosaccharomyces sp.* and *Schizosaccharomyces pombé*.

The inhibitory effect of acetic acid is in proportion to the acid concentration. These results agree with those of Levine and Fellers *(8, 9)* and Cruess and Hascal *(4)*. Combinations of sugar with acetic acid are no more toxic than are the solutions of acid alone. Similar conclusions have been drawn by Levine and Fellers *(9)* and Pederson and Breed *(10)*. Combinations of sodium chloride with acetic acid appear to be more effective than acid alone in checking growth of yeast cultures used in our tests. Levine and Fellers *(9)* and Pederson and Breed *(10)* have found that the addition of salt did not increase the toxicity of their solutions. On the other hand, Heath *(7)* suggests that the addition of sodium chloride will reduce the amount of acid necessary to prevent fermentation in pickles. It may be noted, however, that a combination of 3% acetic acid and 4% sodium chloride is insufficient to prevent growth of *Zygosaccharomyces sp.*, isolated from "cherry olives."

Sodium chloride or sugar alone, in acceptable concentrations, do not serve as effective preservatives for "cherry olives." Pederson and Breed *(10)* made similar observations in their work on tomato catsup. Combinations of sugar and sodium chloride, while showing a greater inhibiting effect than either component used alone, do not prevent growth of the yeasts tested except in extremely high concentrations. Pederson and Breed *(11)* found that the growth of test cultures of bacteria and yeasts, with the exception of one resistant yeast, was stopped by 15% sugar and 3.5% sodium chloride. These concentrations appear to be too low to prevent growth of the more resistant strains used in our experiment.

That sodium benzoate is a more effective preservative at low pH values than at neutrality has been shown by Cruess *(3)*, Cruess and Richert *(5)* and Cruess, Richert and Irish *(6)*. Results of our investigation, using test cultures of yeasts, agree with these observations.

Pederson and Breed *(10)* recommend the use of 1% acetic acid, and 5% sodium chloride, or 15% sugar combined with 3.5% sodium chloride for the preservation of tomato catsup. These combinations would be ineffective against the yeast species responsible for the spoilage encountered in "cherry olives." However, a combination of 2% acetic acid, 2% salt and 30% sugar, while maintaining the palatability of the product, should prevent the growth of most yeasts. The addition of 0.1% sodium benzoate with these concentrations of acid, sugar and salt would prevent spoilage by resistant organisms such as *Zygosaccharomyces sp.*

While the product may readily be pasteurized, the heat treatment adversely affects the appearance of the fruit.

SUMMARY

Variation in the ability of selected strains of yeasts to grow in the presence of acetic acid has been observed. Acid tolerance ranges from extremely sensitive to quite resistant.

Of the acetic acid, sugar and salt components, acetic acid is the most effective single agent in preventing yeast growth. The addition of sugar does not enhance the inhibitory effect of the acid solutions. Sodium chloride increases the preservative action against most yeasts tested, but fails to prevent growth of *Zygosaccharomyces sp.* isolated from "cherry olives," except in high concentration.

Salt and sugar, separately do not prevent yeast growth, except in concentrated solutions. In combination they are more effective than either alone, but again must be used in high concentrations.

The acid-sugar-salt combinations used in the experiment are ineffective against *Zygosaccharomyces sp.* *Schizosaccharomyces pombé* is inhibited at the higher concentrations of acid and sugar mixtures. *Saccharomyces cerevisiae* grows only weakly in the lowest concentrations. *Saccharomyces ellipsoideus* grows in the lowest concentrations of acid, sugar and salt, but is

checked in these mixtures when the acid concentration is increased. *Endomyces vernalis, Candida krusei, Hansenula suavolens* and *Torulopsis utilis* fail to grow in any of the solutions employed.

Zygosaccharomyces sp. isolated from "cherry olives" is quite resistant to 0.1% sodium benzoate. All other yeasts tested are inhibited. Acetic acid intensifies the effect of the benzoate, as does a high concentration of sodium chloride. Sugar does not affect the action of benzoate.

It is suggested that 2% acetic acid with 2% sodium chloride and 30% sugar will prevent the growth of most yeasts in "cherry olives." In order to control resistant types, it is necessary to add 0.1% sodium benzoate.

Pasteurization at 140° to 150° F. (60° to 65° C.) for 10 minutes destroyed the acid resistant yeast encountered in "cherry olives," but lowered the quality of the product.

Acknowledgments

The authors wish to express their appreciation to Dr. C. E. Chaplin, of the staff of the Division of Bacteriology and Dairy Research, Ottawa, Ontario, for type cultures of yeasts used in this experiment, and to Mr. F. E. Atkinson for his interest in the project.

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Microplating and Counting Techniques for Bacteria in Food Products[a]

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(Manuscript received October 18, 1952)

The microplating method described incorporates improvements in bacteriological control procedures for the food industries. It is relatively simple and inexpensive, eliminates eye-strain, and reduces calculations and time required. A film prepared by mixing 0.05 ml. of sample with 3 drops of plating medium on a microscope slide is incubated in a moist chamber for 10 hours and then stained; all the colonies that appear are counted under a binocular microscope using 10× magnification. The stained slides may be filed for permanent records. Results obtained on several kinds of frozen vegetable products show that the microplating method agrees favorably with standard plating procedure.

Bacteriological analyses, which are important in supplementing organoleptic tests in judging the sanitary quality of food, should be sufficiently simple, accurate, and inexpensive to permit rapid routine use in examining food products. The several methods now employed are not entirely satisfactory for modern quality control. Either they involve eye-strain and specialized technical knowledge, or they are time consuming. In an attempt to overcome these difficulties, a study was made of possible modifications of present methods.

There are in general 4 principal methods for estimating the numbers of bacteria in food products: the standard dilution plate method, direct microscopic method, slant culture technique, and the Frost little plate method.

The standard plate count has been severely criticized by many investigators, notably, by Wilson *(11)*, who states: "on account of the difference between various species of bacteria in their nutritional, respiratory, and temperature requirements and most important of all on account of the gross irregularity in the distribution and clumping of the organisms, the plate count merely registers the number of bacterial units capable of multiplying under the particular conditions selected." These facts cannot be denied, but it is the accepted method *(1)*.

The direct microscopic method, described by Prescott and Breed *(8)* in 1910, involves the spreading of a film of milk over a definite area on a microscope slide, staining, and counting the cells through a calibrated microscope. Although various modifications of the Breed method greatly facilitated its use, many investigators believed that further alterations were necessary to assure an accurate method for estimating the total numbers of bacteria in food products. Jennison *(4)* proposed that if the groups of bacteria could be completely broken up,

[a] Published as Technical Paper No. 759 with the approval of the Director, Oregon Agricultural Experiment Station. Contribution of the Department of Bacteriology.

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the plate and direct counts would be practically identical. According to Hanks and James *(3)* there are *2* serious sources of error in the direct microscopic method: loss of bacteria from the slide during staining, and faulty selection of areas for observing and counting cells. Recently Olson and Black *(7)* investigated 5 different stains proposed as substitutes for stains now specified in *Standard Methods*. These yield higher clump counts than the standard stain and possess other desirable characteristics such as less counting fatigue and more accurate results.

Although the direct microscopic method plus its modifications may not be entirely satisfactory, it does under some conditions have considerable value. It is less expensive and more rapid than the plate count and is a reliable method for differentiating food products of high bacteria content from those of low content.

Wilson *(11)* introduced a method for counting bacteria involving replacement of Petri dishes by culture tubes. It was stated that the experimental error between this roll-tube method and the standard technique probably does not exceed 5%. Burri *(10)* developed a standard loop procedure for spreading 0.001 ml. of sample on an agar slant. Rydzowski *(9)* suggested the use of a calibrated platinum wire loop to measure and streak the sample on the surface of a poured Petri plate, thus enabling the testing of several different samples at one time.

Frost *(2)* in 1915 introduced the little plate method in which a microscope slide was used as a plate for a mixture of agar medium and sample. This technique gave fair correlation with the standard plate method. A recent modification of the Frost little plate method, that of Nickerson *(6)*, involves a new type of slide and a different stain and is applicable to frozen vegetables. Its precision was found to be of the same order as that of the standard count; however, the results indicate that representative replicates were not obtained in making duplicate counts from the same sample.

Although most investigators are fairly well agreed upon the accuracy of the Frost little plate method, it has several disadvantages. It requires counting numerous microscopic fields before an accurate estimate of the total number of bacteria is obtained. This is laborious and fatigues vision. In using the original Frost stain, extraneous particles are sometimes mistaken for bacterial colonies, and bacterial counts higher than actual result. Another disadvantage is that the series of calculations required sometimes become involved and mistakes are likely to occur.

Of these several methods and their modifications, each has advantages, but none is sufficiently rapid and accurate or easily applied to meet the requirements for quality control in the frozen food industries.

To reduce the time involved and still maintain accuracy, it would appear that micro-methods are the most applicable. The procedure about to be described is believed to fulfill the requirements for accuracy, rapidity and economy. The method is based on previous techniques, but modifications have been introduced to eliminate eye-strain, simplify calculations, reduce time, and minimize cost.

EXPERIMENTAL

Preparation of sample. A representative 50 g. sample of the vegetable product to be examined was weighed aseptically into a sterile aluminum Waring blending jar. Four hundred fifty ml. of sterile water was added, and the contents blended for approximately 7 minutes. Ten minutes was allowed for foam to subside and coarser particles to settle; the supernatant was then considered a 1:10 dilution. For liquid food products such as milk or fruit juices, the preparation of the sample is much simpler. In this case 11 ml. of the product was added to a 99 ml. dilution blank and shaken thoroughly for a 1:10 dilution. The procedure must be followed as outlined in order to obtain reliable replicate samples.

Preparation of miccroscope slides. Areas approximately 1¼ by ⅝ inches were marked with a wax pencil on cleaned microscope slides. To facilitate the procedure and alleviate the handling of several slides for each sample, *2* areas approximately 20 mm. sq., may be marked on each slide. The *2* areas on one slide may then represent duplicate plates. Just prior to use, these slides were sterilized by dipping them into 95% alcohol and flaming, then placed on a 45° C. warming table and allowed to cool to this temperature. To prevent contamination, slides were used as soon as possible after sterilizing. Marking the area on the slides is not critical since the entire "plate" will be counted.

The medium used was tryptone glucose beef-extract agar.

Bacto-Beef Extract	3 g.
Bacto Tryptone	5 g.
Dextrose	1 g.
Agar	15 g.
Distilled water	1000 ml.
pH 7	

To facilitate handling for microplating, the medium was placed in small test tubes before sterilization, but it may also be dispensed into small pyrex dropping bottles fitted with ground-in pipette stopper and nipple. The medium was melted and held in a small 50° C. water bath ready for use as needed.

A 0.5 ml. quantity of the 1:10 blended sample suspension was transferred to the area previously marked on the microscope slide in position on the warming table. Three drops of the plating medium were added with a sterile 1 ml. pipette. A sterile platinum needle was used to mix the inoculum with the medium and to spread it evenly over the area marked. The slide was then immediately removed from the warming table to a Petri dish moist chamber and incubated for 10 hours at 32° C.

Two microscope slides easily fit into a moist chamber prepared by inverting the top of a sterile 100 mm. Petri dish inside a large sterile 150 mm. Petri dish. Sterile water is added to the area between the *2* dishes to a depth of approximately ¼ inch. This moist chamber accomplishes *2* purposes: first, it maintains the proper humidity for development of the bacteria; and second, it prevents the dehydration of the cultures during the incubation period. The last named function is essential to permit satisfactory staining.

Although use of 0.05 ml. of sample is not essential, it is most convenient. As with the standard plate count method, it was sometimes necessary to increase the dilution with heavily contaminated samples. This facilitated counting procedure and accuracy. Spreading the inoculated medium to an absolutely uniform thickness is not required, as is the case where only a few fields are to be counted.

After incubation, the plates are dried at 90° C. on the warming table—which requires approximately 10 minutes. Drying should take place at a moderate rate. An additional 5 minutes on the warming table should be allowed to insure adequate fixing. If allowed to dry at room or incubator temperature, the films have a tendency to crack and peel or to loosen during the staining process.

With proper technique it was found possible to stain the films so that the colonies are deeply colored, while the substrate remains wholly without color. Success greatly depends on the treatment the films receive before immersion in the stain. The drying process is critical, and for best results must

conform to the procedure indicated. For staining, the slides are immersed for 5 minutes in a solution having the following composition:

5% phenol, aqueous	90 ml.
1% aniline blue, aqueous	8 ml.
Glacial acetic acid	25 ml.

At the end of this time the slides are withdrawn with forceps and held in a slanting position for decolorization. The decolorizing solution, prepared by adding 3 ml. HCl (sp. gr. 1.19) to 100 ml. ethyl alcohol (95%), is allowed to run over the film a drop at a time until no more color is apparently being removed. The films are then allowed to air dry with the slides in an upright position.

Best results were obtained with the above modification of the stain and decolorizer developed by Jones and Mollison *(5)* for a direct count of microorganisms in soil. By increasing the acetic acid concentration of the staining solution from 20 ml. to 25 ml. and by using no water during the staining procedure, greater contrast was obtained. Following application of the alcoholic acid decolorizer the bacterial colonies appear as relatively large blue masses against an almost white background.

TABLE 1

Comparison of microcounts and plate counts on representative frozen vegetable products

Package number	Colony counts				Average of samples	
	Sample 1		Sample 2		Total numbers per gram	
	Micro-count*	Plate count†	Micro-count	Plate count	Micro-count	Plate count
Green peas						
1		53		50		
	335	58	315	52	67,500	54,000
	340	52	324	54	63,900	52,000
Ave.	337.5	54.0	319.5	52.0	65,700	53,000
2		68		60		
	307	70	325	66	62,200	68,000
	315	66	326	72	65,100	66,000
Ave.	311.0	68.0	325.5	66.0	63,650	67,000
3		50		61		
	327	74	300	67	65,700	63,000
	330	66	313	73	61,300	67,000
Ave.	328.5	63.0	306.5	67.0	63,500	65,000
4		81		59		
	250	64	283	63	50,600	69,000
	256	67	285	61	56,800	61,000
Ave.	253.0	69.0	284.0	61.0	53,700	65,000
5		58		60		
	303	69	296	69	61,300	63,300
	312	63	299	75	59,500	68,000
Ave.	307.5	63.3	297.5	68.0	60,500	65,700
Green beans						
1	257	49		47		
	242	42	259	49	50,000	47,000
	251	50	263	51	52,200	49,000
Ave.	250.0	47.0	261.0	49.0	51,100	48,000
2		51		44		
	242	49	246	47	48,600	51,000
	244	53	256	47	50,200	46,000
Ave.	243.0	51.0	251.0	46.0	49,400	48,500
3		104		99		
	515	97	510	105	103,600	102,000
	521	105	518	111	102,800	105,000
Ave.	518.0	102.0	514.0	105.0	103,200	103,500
4		102		100		
	469	109	470	109	94,000	100,000
	471	89	486	118	95,600	109,000
Ave.	470.0	100.0	478.0	109.0	94,800	104,500
5		125		113		
	533	109	538	132	106,600	117,000
	543	130	546	131	108,400	122,000
Ave.	533.0	117.0	542.0	122.0	107,500	119,500
Cut wax beans						
1		53		56		
	221	56	324	66	44,800	61,660
	227	76	330	77	65,400	66,300
Ave.	224.0	61.7	327.0	66.3	55,100	63,980
2		52		46		
	217	51	330	52	43,600	50,300
	219	48	327	58	49,700	52,000
Ave.	218.0	50.3	248.5	52.0	46,650	51,150
3		70		76		
	40	80	49	80	8,800	6,660
	48	50	51	84	10,000	8,000
Ave.	44.0	66.7	50.0	80.0	9,400	7,330
4		47		53		
	340	50	281	60	68,600	49,700
	346	52	289	69	57,000	60,700
Ave.	343.0	49.7	285.0	60.7	62,800	55,200
5		43		36		
	140	45	164	48	28,600	40,000
	146	32	170	54	33,400	45,000
Ave.	143.0	40.0	167.0	45.0	31,000	42,500
6		26		40		
	128	30	180	36	26,100	32,600
	133	42	180	44	36,000	40,000
Ave.	130.5	32.7	180.0	40.0	31,050	36,300
Baby lima beans						
1		68		76		
	106	81	350	78	60,700	73,000
	301	70	352	91	70,200	81,700
Ave.	303.5	73	351.0	81.7	65,450	77,350
2		137		132		
	817	154	800	137	164,200	140,300
	825	140	812	142	161,200	137,000
Ave.	821.0	140.3	806.0	137.0	162,700	138,650
3		42		35		
	203	57	151	37	40,800	47,300
	206	43	155	47	30,600	39,660
Ave.	204.0	47.3	153.0	39.7	35,700	43,480
Mixed vegetables						
1		138		148		
	700	157	665	153	140,600	159,000
	706	162	677	170	134,200	157,000
Ave.	703.0	159.0	671.0	157.0	137,400	158,000
2		169		163		
	766	169	830	169	134,100	170,000
	775	171	837	177	166,700	169,000
Ave.	770.5	170.0	833.5	169.0	160,400	169,500
3		139		125		
	515	154	496	136	104,000	143,000
	525	136	498	147	99,400	136,000
Ave.	520.0	143.0	497.0	136.0	101,700	139,500
4		155		148		
	495	163	507	156	99,400	165,000
	499	177	510	170	101,700	158,000
Ave.	497.0	165.0	508.5	158.0	100,550	161,500
5		49		60		
	268	65	335	58	54,200	57,000
	274	57	343	59	67,800	59,000
Ave.	271.0	57.0	339.0	59.0	61,000	58,000
6		39		56		
	303	45	303	70	61,000	45,000
	307	51	312	45	61,500	57,000
Ave.	305.0	45.0	307.5	57.0	61,250	51,000

*Colonies per slide.

†Colonies per plate.

Counting the colonies. Counting the colonies is accomplished by focusing the stained preparation under a wide field binocular microscope using a 10 × magnification. The slide is moved across the field as required to count all the colonies appearing in the entire area of the film. Since 0.05 ml. of a 1:10 dilution is used to prepare a "plate" the dilution factor is 200. Therefore, multiplying the number of colonies counted by 200 gives the number of bacteria per g. of product.

To aid in counting, the reverse side of the slide may be ruled with a diamond point pencil to eliminate confusion in counting each plate on the slide; this serves the same purpose as the ruled areas on conventional apparatus.

RESULTS

The foregoing procedure was applied to duplicate samples taken from each of 3 to 6 randomly selected packages of several different frozen vegetables, packed in 1951 by a leading food processing firm. Standard plate counts were made at the same time for comparison. The same culture medium and incubation temperature were used in both methods. It was convenient to make microcounts in duplicate, since 2 microplates could be prepared on a single slide. Triplicate plates of 1:1000 dilutions were made for the standard plate counts.

Results are presented in Table I. The standard plate counts gave results that may be considered typical of a normal product in each case. In general the microcounts are slightly lower than the corresponding standard count; for 8 of the 25 packages, the microcounts are higher. Differences greater than 10% occur in only a few cases. On individual samples, duplicate microcounts agree more closely than the counts on triplicate standard plates.

DISCUSSION

The results of bacterial counts by the micromethod indicate that this technique gives reliable estimates of bacterial population in frozen foods. Since agreement with plate counts is considered satisfactory, the micromethod could be of considerable help in rapidly evaluating the sanitary condition of food products. Only one-fourth the time needed for the standard agar plate method is required—a saving due mainly to the decrease of 38 hours in incubation time.

Different counts on the same sample show less variation by the micromethod than by the standard agar plate method. Since a relatively larger amount of sample is used with the microtechnique than with the ordinary plating procedure the former method should theoretically be the more accurate. Since only a few relatively simple operations are required, a technician can become proficient in a short time. Because microscope slides are substituted for Petri dishes and the amount of medium required is not over one-twentieth of that used by the standard agar plate method, the method is economical.

In other methods high magnification (*ca* 440X to 970X) is necessary and many fields must be counted for each sample. The young colonies appear as deep blue masses against a white background in this micromethod, are of sufficient size within 10 hours to be readily observed, and can be counted in approximately 10 minutes with a wide field binocular microscope. Moreover, the slide plates are easier to count than ordinary dilution plates and spreaders do not have time to develop and confuse the enumeration. Although the dilution may have to be increased with highly contaminated products—as with the standard agar plate count method—the 0.05 ml. sample is satisfactory for counts as high as 100,000 bacteria per g. Since colonies are counted, only viable cells are enumerated and the results are therefore interpretable on this basis. This is a distinct advantage over direct microscopic counts that include non-viable as well as living cells. Still another desirable feature is the permanent record provided by the slides with the stained and dried films. These may be filed, thus giving control officials actual evidence on specific samples.

SUMMARY

The microplating method described provides an improvement in laboratory control procedures that could be helpful to the food industries in their endeavors to increase quality of their products. It combines accuracy, simplicity, economy and reliability in the study of sanitary control problems in frozen food industries.

The results of bacterial counts made by standard dilution plate and microtechnique methods indicate that either procedure could be useful in evaluating the sanitary condition of food products. In most cases, different counts on the same sample show less variation among themselves by the micromethod than by the standard plate method, and the counts obtained by one method were approximately of the same reliability as those obtained by the other. The short incubation period required with the micromethod should effectively aid development of quality control measures in food-processing plants.

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Effect of Processing Conditions on Organoleptic Changes in Foodstuffs Sterilized with High Intensity Electrons[a]

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(Manuscript received July 24, 1952)

Although penetrating ionizing radiation is now recognized as an efficient means for effecting heatless sterilization of foodstuffs, it may adversely affect their flavor and texture. Commercial radiation sterilization of food will thus depend largely on development of techniques which reduce or eliminate objectionable organoleptic changes or other adverse side effects such as changes in color, physical characteristics, etc., without increasing markedly the energy requirements for sterilization. A number of such techniques, both physical and chemical in nature, are described. Among them are irradiation in the frozen state, in vacuum, under inert gases, in the presence of chemical protectors, and with the elimination prior to irradiation of oxygen dissolved in the foodstuff. So far, protective methods have been investigated only on an experimental scale, and their final evaluation awaits successful operation under commercial processing conditions. Findings are, however, that foodstuffs irradiated at dose levels assuring commercial sterility can usually be protected against radiation-caused flavor changes by proper selection and combination of such techniques.

Commercial sterility by definition implies the destruction of all organisms which might develop under ordinary conditions of food processing and storage. A large number of investigations *(5, 13, 18, 19, 25)*, particularly during the last decade, have shown penetrating ionizing radiation to be a reliable method for obtaining commercial as well as bacteriological sterility.

Of the available ionizing radiations, high intensity electrons *(11, 21, 29)* are particularly well suited for this purpose, due to their defined penetration range, ease of generation at high energy levels, high biological efficency, penetrability of all types of packing material, ready control and ease of protection of personnel.

Foodstuffs generally are heterogeneous mixtures of ampholytes, electrolytes, nonelectrolytes and inert substances, with the total solid content varying between 5% and 30%. For many such products, commercial sterility has been obtained with a dose of high intensity electrons equivalent to 1.5×10^6 rep, the acceptable margin in packaged products being 10^4 organisms/g. On the basis of 1 rep[b] ~ 100 erg/g., the dose of 1.5×10^6 rep corresponds to 1.5×10^8 erg/g., 15 joule/g., 15 watt sec./g., and/or 1.5×10^{-2} B.t.u./g. The fact that the absorption of such a dose causes a temperature rise of only 3.7° C./g. in water characterizes this technique as heatless preservation and allows, therefore, sterilization in the raw state also.

Although the typical changes characteristic of heat processing are absent in irradiated foodstuffs, other—sometimes undesirable—effects on taste, odor, color and texture nevertheless can occur *(4)*; often these effects are strong enough to require protective processing techniques prior to and during irradiation in order that a sterilized product, organoleptically acceptable, may be obtained.

The data in this paper have been assembled with the purpose of describing a number of techniques which seem to offer promise for the sterilization of food products with ionizing penetrating radiation in such a manner that the irradiated product is fully acceptable in flavor, color and appearance. The authors have attempted to illustrate the usefulness of the techniques with representative examples from their own work, which has been carried out during the last 4 years using a Capacitron as the source of the ionizing penetrating radiation. Due to the nature of this paper, the experimental evidence is presented in a concentrated form and should be considered as principally illustrative, the detailed experimental evidence to be published in due course.

PROCEDURAL CONSIDERATIONS

Since the preservation of significant organoleptic qualities is of great importance for successful radiation sterilization, the usefulness of a protective technique should, in addition to analytical methods, always be tested by odor, taste and appearance evaluation of the irradiated foodstuffs. In our work the taste panel was usually composed of four to six experts trained in testing the products under examination. They had no advance information of the tests that might influence their judgment. In all cases, the evaluation was carried out in the same physical location with the identity of the individual samples hidden by coding. The panel members tested individually and without knowledge of the results from the rest of the panel. Generally, at least 2 samples of identical treatment were tested by each panel member, together with a control which had been treated identically in every respect except that it had not been irradiated. In cases of close similarity between control and treated product, the degree of protection was further tested by a triangle technique incorporating separate evaluation of odor, taste and appearance, and if advisable followed by an over-all evaluation. In many cases, the foodstuffs were evaluated both raw and cooked. The flavor scores in the tables are averages of the panel findings and are based on the following scale: 1, *poor*; 2, *borderline*; 3, *satisfactory*; 4, *good*; and 5, *excellent*. Under this scoring system, the untreated control was in each case arbitrarily designated *excellent*. No attempt has been made to standardize the controls beyond the fact that they were identical in origin to the respective irradiated products. Hence, the flavor scores can be considered as relative only, and no statistical analysis of the results is presented at this time. It is considered that these tests are chiefly useful as a screening device for the relative protective values of various processing techniques.

It should be emphasized that the complex mixture of chemical compounds which represents a "foodstuff" is susceptible to

[a] Presented at the Twelfth Annual Meeting of the IFT, Grand Rapids, Michigan, June 8, 1952.

[b] The term "rep" is an abbreviation of "Roentgen equivalent physical," *(10)*, a unit indicating the amount of energy absorbed in the form of ionizing radiation.

a great diversity of changes during irradiation with high intensity electrons. Hence, it would be optimistic to expect any one processing technique to be a cure-all for adverse side reactions encountered in radiation sterilization. We find that different foodstuffs will, more often than not, require variations in processing techniques, depending upon their composition, the most resistant type of organism liable to be present, its maximum expected concentration, etc. Even such related items as different cuts of meat from one carcass may require somewhat divergent processing techniques for successful radiation sterilization.

The general reluctance to use chemical additives in foodstuffs *(11)* makes methods of radiation protection of a physical nature advantageous. We have therefore investigated such methods, and in the text that follows, several of the more promising approaches of this type will be presented.[4]

Table 1 shows a number of processing techniques which can be applied either prior to or during irradiation, and which we have found helpful in reducing or eliminating detrimental organoleptic changes. The second column in Table 1 indicates the sterilization dose necessary for a specific processing technique, and it can be seen that a dose of 1.5×10^6 rep $\pm$ 10% is satisfactory to obtain commercial sterility, regardless of type of processing technique. This dose is based on an average contamination with organisms commonly found in commercial food processing.

TABLE 1

Influence of conditions during irradiation on sterility dose

Processing technique	Sterility dose (rep)
Freezing	$1.5 \times 10^6 \pm 10\%$
Vacuum	$1.5 \times 10^6 \pm 10\%$
Inert gases	$1.5 \times 10^6 \pm 10\%$
Pre-storage	$1.5 \times 10^6 \pm 10\%$
Chemical protectors	1.5×10^6; less if protector per se bacteriostatic
Flash heating in combination with irradiation	0.5 to $1.0 \times 10^6 \pm 10\%$
Dose rate	$1.5 \times 10^6 \pm 10\%$

Our data seem to be at variance with the results of Hollaender *et al. (17)*, which indicate that *E. coli*-B/r and other vegetative bacteria were considerably more resistant when irradiated under anaerobic conditions or in the presence of nitrogen. Such an effect, if applicable to all types of microorganisms commonly occurring in foodstuffs, would make it appear that radiation sterilization in vacuum or in nitrogen would require increased doses of radiation, thus negating the possibility of a beneficial effect. The apparent discrepancy between our results and those of Hollaender *et al.* may well be due to the great differences in dose rate inherent in the *2* techniques of irradiation. Another possible explanation may lie in the fact that the sterility dose of 1.5×10^6 rep $\pm$ 10% is determined in most foodstuffs by the presence of spores; hence if the inactivation of bacterial and other spores were not dependent upon the atmosphere existing during irradiation,[4] this would explain our findings, since even though vegetative cells may be considerably more resistant in an inert atmosphere or in vacuum, a dose of 1.5×10^6 rep would seem to be more than ample to inactivate all such cells prior to the inactivation of spores.

[3] The irradiations were carried out with high intensity electron bursts obtained from a *3* MV Capacitron. The electrons are emitted from the generating tube into the air in bursts of about one microsecond duration, with each burst containing an energy equivalent to hundreds of millions of rep gram. The equipment, the technique of irradiation and the dosage calculations have been thoroughly described elsewhere *(20)*.

[4] Investigations in this direction are now under way in our laboratories. In the case of some viruses (rabies, YSK, Brunhilde-Polio) no significant increase in resistance was found on irradiation under inert conditions with high intensity electron bursts.

TABLE 2

Inactivation doses with high intensity electron bursts in liquid and frozen state

Organism	Medium	D_{37} (rep) at 10° C. and −35° C.
E. coli	Broth 2×10^{10} org./ml.	8,200
M. lysodeikticus	Broth 1.2×10^9 org./ml.	12,500
S. marcescens	Broth 1.1×10^{10} org./ml.	8,500
B. subtilis spores	Broth 7.4×10^6 org./ml.	40,000
E. coli bacteriophage	Broth	
T2r+	1.7×10^9 org./ml.	37,500
T3	2.1×10^9 org./ml.	56,500
Rabies virus	5% brain emulsion in broth Titer: $10^{-6.5}$	52,000

Freezing. As indicated in Table 1, the sterility dose is not materially altered whether a sample is irradiated at room temperature or in the frozen state. This is further shown by Table *2*, which contains the *37%* survival doses for several bacteria and bacterial spores, taken at 5° and −35° C. No increase in dose was found necessary due to irradiation in the frozen state. Contrary to this, and distinct from the beneficial effect of low temperature in general, the radiation effect on various food constituents can be considerably minimized if the product is kept frozen solid during the irradiation *(20)*. This "sparing effect" is due to the fact that the diffusion rates of radicals and the reactivity of radical acceptors are drastically reduced on freezing. In addition, there may be a concentration or separation of the solute during solidification, with corresponding reduction of chemical effect.

Figure 1 shows this for solutions of ascorbic acid irradiated in water with increasing doses at 18° C. and −35° C. *(22)*; a much greater protection of ascorbic acid is obtained on irradiation in the frozen state. Orange juice provides additional protection, since the solids of the juice act as capturing agents and thus diminish the vitamin inactivation of a sterility dose of electrons by additional factors of about 4 at 18° C. and about *2.5* at −35° C. Similar effects were demonstrated by Proctor and O'Meara *(27)* working with cathode rays obtained from an electrostatic generator.

Role of oxygen. On examination of the factors involved in organoleptic changes due to sterilization with high intensity electrons, one finds that oxygen plays a crucial role in the initiation as well as the propagation of underlying chemical changes. It is important to realize that both the oxygen *surrounding* the foodstuff, as well as the oxygen dissolved in the foodstuff, are subject to activation by ionizing radiation, followed by interaction with suitable acceptor groups in the foodstuff, the net result being changes in taste, odor, color or texture. Consequently, in foodstuffs, these changes are drastically reduced or eliminated when they have been thoroughly freed of oxygen prior to the irradiation.

Methods for the exclusion, removal and neutralization of oxygen, therefore, become of prime importance in the radiation processing of many foodstuffs. We have found that a variety of methods can be successfully adopted for this purpose, with the proper choice depending upon considerations such as the physical state of the food, the type of packaging, ease of adaptation to food processing, etc.

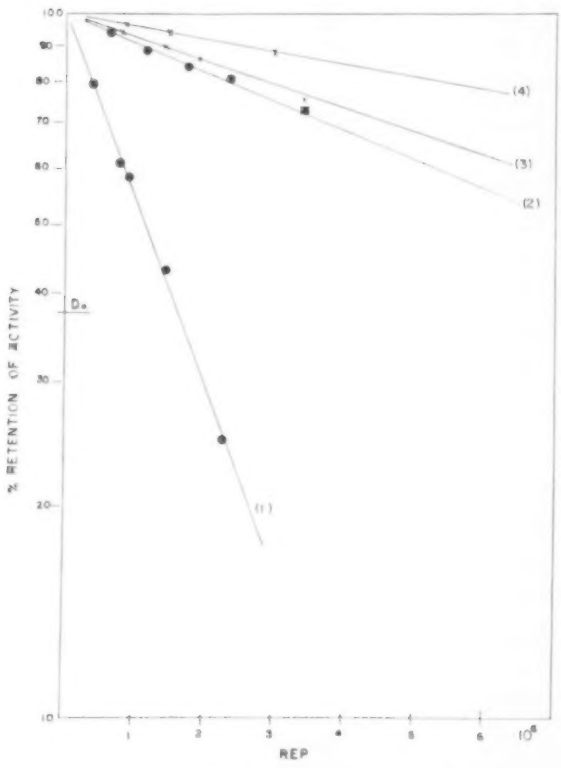

Figure 1. Inactivation of ascorbic acid with high-intensity electrons in different media. Ascorbic acid conc. : 1.3 mg./g. (1) 0.5% aqu. AcOH, 18° C., D_0 = 1.6 × 10^6 rep; (2) 0.5% aqu. AcOH, —35° C., D_0 = 11.5 × 10^6 rep; (3) orange juice, 18° C., D_0 = 12.6 × 10^6 rep; (4) orange juice, —35° C., D_0 = 23 × 10^6 rep.

Vacuum and inert gases. Foods packed in gas-tight containers can of course readily be evacuated and subsequently irradiated either while under vacuum or after replacement of the vacuum by an inert gas such as nitrogen, helium, hydrogen, etc. In cases where the food is semi-solid, such as in puree or paste form, the dissolved as well as the adsorbed oxygen can be removed by vacuum deaeration in thin enough layers. Packing with minimal head space is also advantageous, since we notice that the larger it is, the more pronounced the adverse reactions. We do find, however, that vacuum packing as generally practiced in the food industry, e.g., evacuation by about 26 inches, is in most cases not sufficient to avoid flavor changes. Here methods must be used which assure a much more thorough removal of the oxygen, and sometimes the residual oxygen should not exceed 5% of saturation. Since such vacuum installations, although available in other fields, are not usually found in food processing plants, techniques designed towards the procurement, preparation and packaging of foodstuffs with a minimum of exposure to oxygen acquire added importance for use in conjunction with radiation sterilization.

In the sterilization of foodstuffs heated prior to irradiation the new technique also proves attractive, since it is now possible to cook products only to maximum palatability—sterilization being carried out subsequently with high intensity electrons. The cooking process in itself usually expels or neutralizes a large part of the dissolved oxygen, and if the subsequent packing is carried out in a manner to obtain maximum oxygen removal, we find that organoleptic changes are usually not detectable in a variety of precooked products, such as soups, stews, sauces, baby foods, etc.

The effect of vacuum and nitrogen packing on the rancidity development in various fish oils has already been reported by us *(1)*. It was found that, contrary to irradiation in air, there is no noticeable increase in peroxide values if the irradiation is carried out in vacuum or under nitrogen. The organoleptic changes in such oils apparent on irradiation in air are also eliminated by irradiation in vacuum or nitrogen. These findings are parallel to observations with electron-sterilized whole eviscerated mackerel and white fish, as well as the fillets obtained from these fish. In these cases, both vacuum or gas packs eliminated organoleptic changes as well as rancidity development.

Another impressive example of the pronounced effect of vacuum processing is the retention of fresh green color in a puree of electron-sterilized raw peas, as contrasted with the rapid loss of green color in an air-packed sample treated with the same dose.

Stripping. Stripping with inert gases such as nitrogen, helium and hydrogen is a convenient method of oxygen removal from liquid foodstuffs, and has the additional advantage that, in many cases, it permits the retention of valuable volatile components often lost in vacuum processing. We find that by the use of counter current flow, proper adjustment of column height, gas flow and bubble size, it is possible to remove over 99% of the dissolved oxygen from liquids such as milk or juices. The ready availability of nitrogen of high purity, as well as its reasonable cost and good stripping efficiency *(3)*, recommend this gas for oxygen removal from many liquid foodstuffs. Rare gases such as helium and argon work equally well, but for many uses are, of course, much too expensive. Stripping with hydrogen represents a special case, since we find that it provides additional protection over and above replacement of oxygen; that is to say, under identical stripping conditions it is possible to obtain irradiated products of superior organoleptic qualities. The additional protective effect of hydrogen over inert gases again emphasizes the role of oxygen as a key intermediate in the formation of taste, odor and color changes in irradiated foodstuffs. Preliminary results indicate that this phenomenon is due to the increased capacity of activated molecular as well as atomic hydrogen to capture oxygen radicals and thus act as an efficient blocking agent for its interaction with receptors in foodstuffs. The small molecular weight of hydrogen also facilitates its uniform distribution throughout the foodstuff during the stripping operation, and may well be an added reason for its increased efficiency of protection.

Irradiation subsequent to stripping is either carried out after packing, or in conjunction with stripping by

flowing the material in the same gas atmosphere through radiation-permeable tubes or troughs, with subsequent aseptic filling. In the latter operation, the containers can either be pre-sterilized by conventional means or by exposure to the electron beam prior to filling and again directly before or after closing.

Organoleptic changes caused in dairy products by sterilization in air with high intensity electrons are particularly objectionable. Table 3 shows the effect of

TABLE 3

Influence of gas-stripping on flavor of chocolate beverage sterilized with high intensity electron bursts [a] Dose: 1.2×10^6 rep; stripping temp: 5° C.; count: 2×10^5 org. × ml.$^{-1}$

Method	Flow rate ml. × min.$^{-1}$	Stripping time min.	Oxygen removal percent of saturation	Flavor [b]
Air		45	0	1.4
Nitrogen	40	45	>95	3.6
Helium	30	40	>95	3.3
Hydrogen	25	30	>95	4.4

[a] Composition: malted milk, non-fat milk solids, sugar, chocolate, flavoring materials, salt and stabilizer.

[b] Values are averages of 5-member taste panel. Unirradiated control arbitrarily rated as 5.

stripping with nitrogen and hydrogen on a beverage containing milk powder, egg, sugar and chocolate flavoring, which was subsequently sterilized with a dose of 1.2×10^6 rep. The total bacterial count prior to irradiation was about 2×10^5 organisms/ml. The protective effect of stripping is quite satisfactory, with hydrogen stripping being the superior technique. Comparable results were obtained with other flavored milk drinks and a number of vegetable and fruit juices *(7)*.

Pre-storage. While stripping and vacuum-deaeration are satisfactory methods for the removal of dissolved and occluded oxygen from liquid and semi-liquid foodstuffs, they are of little help in the removal of dissolved oxygen from solids. This is of course due to the lack of direct contact between the inner surfaces of the foodstuff and the vacuum space, and the low rate of gas diffusion through the material. Prolonged evacuation, furthermore, causes pronounced dehydration and removal of valuable volatile components, effects which are objectionable per se, and particularly so in the preservation of raw foods.

Prompted by these shortcomings, a simple processing technique has been developed to inactivate occluded and dissolved oxygen in raw solid foods of vegetative as well as animal origin. This technique is based on the utilization of oxygen by tissue, causing an increasing reduction of oxygen in and around the cells *(23)*. In practice, the raw foodstuff is packed into gas-tight containers with the head space as small as possible. Where necessary, the surrounding gas phase can be reduced by partial evacuation prior to closing. Between packing and irradiation the products are submitted to a pre-storage process at temperatures adequate to avoid spoilage of the product. The pre-storage period is continued until the cell metabolism has reduced the available oxygen to a level low enough to permit radiation sterilization without objectionable flavor changes. The length of pre-storage and the temperature during pre-storage depend upon the rate of cell metabolism as well as on the amount of dissolved oxygen, the prerequisite for success being that the total available metabolic capacity is always in excess of the total oxygen content.

In our experiments, we have used up to 96 hours of pre-storage at reduced temperatures. The temperature range generally varied between 4° C. and —35° C., although in some instances we have pre-stored in liquid nitrogen in order to test the limits of the method. The continued ability of animal as well as vegetative cells to bind oxygen at temperatures as low as —180° is noteworthy and of great usefulness in the pre-storage of products likely to spoil rapidly at higher temperatures. It is thus possible to stop the spoilage reactions while the oxygen-binding effect still occurs at sufficient speed to permit satisfactory sterilization with high intensity electrons after pre-storage periods of anywhere from 24 to 96 hours. Once the dissolved oxygen is bound or used up, the irradiation can usually be carried out at any appropriate temperature.

This pre-storage technique has been of considerable value in the elimination of taste, odor and color changes in a variety of radiation-sterilized raw meats. The pre-storage technique also shows promise with vegetables such as beans, spinach, turnips, beets, asparagus, potatoes; and such fruits as pineapple, pears, peaches, berries and cherries. In those vegetables and fruits where enzyme activity remaining after irradiation would interfere with keeping qualities, flash blanching was found adequate for enzyme inactivation and assures satisfactory keeping qualities.

Table 4 demonstrates the effect of pre-storage on color and flavor of a variety of red muscle meats, which

TABLE 4

Effect of pre-storage on organoleptic qualities of raw muscle meat sterilized with high intensity electron bursts

Product [a]	Pre-storage conditions		Organoleptic evaluation [b]		
	Time (hours)	Temp. (° C.)	Odor	Taste	Color
Beef muscle (sirloin steak)	24	3	2.5	2.8	1.5
	24	—15	3.0	3.5	4.5
	72	3	3.0	2.8	2.8
	72	—15	4.8	4.5	4.5
	72	—35	5.0	4.0	4.5
	72	—180	4.5	4.5	4.5
	96	3	3.8	3.0	3.5
	96	—15	4.8	4.3	4.5
Veal muscle (loin chop)	24	—15	3.3	3.5	4.3
	72	—15	4.5	4.3	5.0
Pork muscle (loin chop)	24	3	3.5	3.0	4.0
	24	—15	4.5	3.5	4.5
	72	—15	5.0	4.8	5.0
	96	—15	5.0	4.8	5.0

[a] 30 g. samples packed into aluminum cans 12 × 78 mm. dose: 1.5×10^6 rep.

[b] Values are averages of 5-member taste panel obtained within 1 to 6 hours after irradiation. Unirradiated controls kept frozen until time of testing and arbitrarily rated as 5 throughout. Flavor changes are much less pronounced after cooking.

when irradiated in air with doses in excess of 150,000 rep develop a brown discoloration of the pigment, and acquire an objectionable oxidized flavor. The radiation sensitivity decreases from beef to lamb to veal to pork. It is evident from the table that pre-storage under

proper conditions permits sterilization with 1.5×10^6 rep without objectionable flavor or color changes. The protective effect of pre-storage may well be the end result of an enzymatic binding of oxygen in and around the tissue cells, thus causing a significant reduction of radio-decomposition products per unit dose.

Protectors. That chemical compounds can act as radical interceptors has been reported many times *(18, 9, 14, 20)*, and the literature in the field has been reviewed by Selle *(28)* and by Patt *(24)*. The possible use of radical interceptors in the protection of foodstuffs has recently been discussed by Proctor *et al. (26)*. With ample evidence of this protective effect, interest centers on which of the various chemical compounds added to food act as interceptors to prevent undesirable changes in organoleptic properties. It should be emphasized that the list is limited by the strictures of the U. S. Food and Drug Act.

Prior to the publication of the work by Proctor *et al.* we had independently investigated the potential value of a number of chemicals in the protection of irradiated foodstuffs. It may be of interest that our own search has yielded several groups of compounds, in themselves of food origin, which proved to be excellent interceptors of radicals commonly formed during irradiation of foodstuffs.

We observed, for instance, that a variety of spices, herbs and seeds, as well as extracts prepared from them, exhibit a positive protective effect. Careful evaluation of experiments with these compounds has demonstrated that the protective effect is independent of the fact that the spice itself is likely to impart a characteristic flavor quality, which can to some extent mask the radiation-caused organoleptic changes. The following are examples of spices which will exhibit marked protective qualities when small amounts are incorporated into foodstuffs prior to irradiation, either alone or in mixture: pepper, mace, allspice, turmeric, celery, dill, caraway, thyme, onion and sage.

Table 5 illustrates the protective effect of mace on a fish paste prepared from fish muscle, milk, starch and salt. By irradiation of various samples leaving out one or more of the ingredients the value of this spice in protecting the flavor qualities of the product is thereby made clear. The results also indicate that the maximum protective efficiency is exhibited by a combination of starch and mace, indicating that starch may play a role as carrier molecule for the spice.

TABLE 5

Influence of composition on taste of electron sterilized fish paste. Dose: 1.5×10^6 rep

Ingredients[1]	Weight	Composition				
	g	a	b	c	d	e
Fish filet	100	+	+	+	+	+
Milk	75	+	—	+	—	+
Starch	7	—	+	—	+	+
Salt	2	+	+	+	+	+
Mace	0.1	—	—	+	+	+
Taste		1.2	2.0	3.3	4.1	5.0

[1] Ingredients mixed and heated in can for 10 min. at 75° C. prior to irradiation. Taste values are average of 5 member panel. Controls for each composition arbitrarily set at 5.

Pork sausage meat, which contains a variety of spices, can be irradiated with doses up to 5×10^6 rep without developing any objectionable flavor or color changes.

The observation that variety meats such as liver, kidney, spleen, thymus and brain show little or no organoleptic change even when irradiated in air and with very high doses of electrons, gave a clue to another group of protectors which has proved particularly successful in the radiation sterilization of meats and other products of animal origin. Addition of less than 1% of a homogenate or a cell-free press juice obtained from one of the above-mentioned tissues is generally sufficient to protect against adverse flavor and color changes caused by the irradiation. So far, we have not observed any species dependence of this protective effect, and attempts are now under way to isolate the protective principle from liver.

Chemical protectors are quite specific in their activity. The amounts that can be added to foods are limited by legal considerations, as well as by the flavor properties of not only the additives but also the foodstuffs. We therefore feel that they are valuable principally in conjunction with one of the above discussed physical methods of oxygen removal. Of the legally permissible additives, we have found ascorbic acid and its derivatives useful as flavor and color protectors in fish and fruit products *(7)*; gallic esters and similar polyphenols useful for oils and fats *(1, 15, 16)*; tocopherol, alone or in combination with ascorbic acid, citric acid, etc., useful for vegetable and fruit products, as well as certain cured meat products *(7)*.

Post-Irradiation Storage

In a variety of canned products, it has been found that *post-irradiation* storage proved beneficial in that there was a marked reduction or even disappearance of flavor changes, and a recovery of color to levels comparable with an unirradiated control. In all such instances, the flavor and color changes had been marked directly after irradiation. The time necessary for *come-back* varies with the product, the dose, and the degree of flavor and color change, and in some instances post-irradiation storage periods of several weeks are necessary for recovery. The storage temperature should preferably be controlled, and in our experience storage between 5° C. and 20° C. is usually best suited for uniform recovery. So far, we find this method most useful with meat products, fish products and certain cheeses *(7)*. It was also observed that the recovery is not always the same for all flavor and color qualities; that is, there is sometimes color recovery without flavor recovery, and on occasion some of the flavor components do not come back while others return to normal. Also, post-irradiation recovery is usually more pronounced in raw than in cooked or processed food products.

Color recovery in raw beef muscle, although complete and indistinguishable from an unirradiated control, proved to be the end result of a rather complex and not yet fully understood reaction. Both hemoglobin and myoglobin undergo a typical brown discoloration when irradiated in air. Superficially, the pigment looks much like methemoglobin, but closer examination reveals chemical as well as physical differences which indicate that the pigment formed by the action of high intensity electrons is different from methemoglobin.

On storage, in the dark and in a closed container, the brown pigment will turn into a red one which in appearance resembles oxyhemoglobin. Closer examination, however, reveals that this

pigment is different from the native heme pigment in that it does not change color on further irradiation.

It is possible to protect the native pigment of muscle tissue with a short dip in citrated fresh beef or other animal blood. Subsequent sterilization in air with high intensity electrons will not change the muscle pigment due to this protective effect. That this is a genuine protection can be shown by re-irradiation of the muscle tissue after removal of the protective blood coating. The tissue pigment will then undergo the typical aforementioned color change to brown, even with doses considerably below the sterilization level.

Combination of Heat and Radiation

Sterilization by a combination in quick succession of flash heating and irradiation will merit consideration with foodstuffs such as dairy products which undergo particularly pronounced flavor changes due to irradiation. Table 6 shows an example where such a combination proved not only additive but synergistic, permitting the sterilization of whole raw milk with only one-third of the usual dose, with a corresponding reduction in flavor changes. It is interesting to note that heating just *prior* to irradiation seems to be considerably more effective than heating after irradiation. In each case, the processes were carried out with a minimum time interval. Utilizing this technique (Table 6), it was possible to obtain a sterile milk, with 30 seconds of heating (temperature of the sample 73.5° C.), followed within 10 minutes by irradiation with 500,000 rep. The taste panel rated the flavor of this sterile product only slightly below that of an unirradiated fresh control.

TABLE 6

Synergistic effects of heat and electron radiation on whole, raw milk

Method [a]	Temp. °C	Time sec.	Dose rep × 10^{-3}	Bacteriological data [b]	Flavor [c]
	73	30	300	Growth	
Heating *prior* to irradiation	73	30	500	Sterile	Good
	74.5	45	300	Sterile	Good, slightly cooked
	74.5	45	500	Sterile	Fair, slightly cooked and oxidized
	0	0	300	Growth	
	0	0	500	Growth	
	73	30	0	Growth	
	74.5	45	0	Growth	
Heating *after* irradiation	74.5	45	500	Growth	
	74.5	60	500	Growth	

[a] 30 g. raw milk canned; can heated in water bath to proper temp.; then immediately immersed in ice water; irradiation on crushed ice; interval between irradiation and heating not more than 10 minutes.

[b] Aerobic and anaerobic plating after 3 day incubation at 30° C. Count prior to irradiation 2×10^6 org. × ml^{-1}.

[c] Values are averages of a 5 member taste panel.

Another effect was observed with products of high starch content such as grain, rice and beans which had been treated with smaller doses of electrons for reasons of insect, mold and fungi elimination. In this case it was found that irradiation with 500,000 rep materially reduced the cooking time of the sample and in several instances also the degree of absorption of cooking water. The differences in cooking time were determined empirically by cooking both unirradiated control and irradiated product to the same degree of palatability. The determinations of water absorption were carried out by cooking under reflux and subsequent determination of the volume of water remaining after straining the cooked product at about 30° C.

Table 7 illustrates this effect for a number of typical examples, and it can be seen that in some instances the cooking time is reduced by as much as 50% and that in some cases appreciable differences exist in the amount of water absorbed by the irradiated product during cooking. Texture changes were also observed in that the cooked products often were softer than the unirradiated cooked controls. In the case of popcorn, popping time was reduced by over 50% and the yield of popped product was higher than that of the unirradiated control.

Dose Rate

An increasing amount of experimental results in the field of applied radiation have demonstrated the influence of the time in which a given dose of radiation is applied on the yield of the chemical reaction. These differences can be very pronounced (6) in systems where the effect is due to interaction with radicals formed by the radiation, since their steady state concentration is dependent upon their rate of formation. As the rate of formation of radicals increases, so does the recombination, and consequently the number of radicals available for reaction with the solute decreases.

TABLE 8

Color retention in aqueous tartrazine solutions [a]

Type of radiation	Total dose 10^6 erg × g.$^{-1}$ [b]	Number of pulses	Relative dose rate	Percent color retention
Electrons	8	1	1	75
	8	2	0.5	60
	8	3	0.333	54
	8	6	0.167	43
	8	9	0.11	38
	50	1	>6	38
	61	14	0.071	4.7
Gamma rays	8	Continuous	10^{-3}	4.7

[a] Tartrazine: (trisodium salt of 3-carboxy-5-hydroxy-1-p-sulfophenyl-4-p-sulfophenylazopyrazole, MW 468); dye conc., 0.01%; oxygen saturated water.

[b] 1 erg ~ 0.01 rep.

The dose rate effect can be demonstrated by exposing solutions of tartrazine to identical dose but varying dose rates. In Table 8 the results of such a series of experiments are recorded. For the same dose of 80,000 rep, the retention varies from 75% to 38% if the dose rate is varied by a factor of 9. For the gamma rays of Co-60, the color retention is only 4.7%. In order

TABLE 7

Reduction of cooking time in products of high starch content. Dose: 0.5 × 10^6 rep

Product [a]	Cooking water ml.	Cooking time min.		Water absorption percent cooking water		Texture irradiated cooked compared to control cooked
		Control	Irradiated	Control	Irradiated	
Rice, white polished	260	15	8			Softer
Cream of Wheat	390	13	8	110	92	Softer
Oatmeal	390	13.5	7	100	95	Softer
Green peas, split, dried	260	19	9	100	84	Same
Lima beans	260	24	19	94	76	Softer
Green peas, whole	260	54	44	97	90	Softer
Black turtle beans	325	83	58	100	81	Softer
Elbow macaroni	390	11	8	50	38	Softer
Pop corn [b]	0	8.4	4.1	—	—	Same

[a] Weight of sample: 65 g. Salt added to cooking water: 1 g.

[b] Yield: control 7%; irradiated 98%.

to obtain the same retention with electrons, a much higher dose is necessary.

If the retention obtained previously with 9 pulses and 80,000 rep is attempted with one pulse, more than 500,000 rep are needed to reach a 38% retention. A dose rate dependence could also be demonstrated for hydrogen peroxide formation in acid, oxygen saturated aqueous solutions. In this case, the over-all concentration, at 300,000 rep for instance, is less by a factor of about 3 for gamma rays from a Co-60 source.

Similarly, the effect on flavor and color in foodstuffs can be appreciable, and in many instances high dose rates will be of considerable benefit in avoiding organoleptic changes. Working with raw milk, we find that the pronounced organoleptic changes due to irradiation are greatly reduced by using high dose rates. When this technique is used in connection with vacuum flashing or stripping, the product after sterilization is practically free of all objectionable flavor change.

SUMMARY

A number of methods are described which, utilized separately or in combination, permit sterilization of a variety of raw and processed foods with high intensity electron bursts without detrimental flavor changes. These processing techniques are used either prior to or during irradiation and are of physical as well as chemical nature.

They include irradiation in the frozen state, irradiation in the absence of oxygen, and irradiation in the presence of radical acceptors.

Oxygen was shown to be one of the principal factors responsible for radiation initiated organoleptic changes. In many instances the oxygen threshold values were found to be as low as 1% of saturation.

Special methods for oxygen removal were therefore developed, including counter-current stripping with inert gases, and a technique of pre-storage in closed containers at controlled temperatures.

Organoleptic changes caused by ionizing radiation proceed to a large extent via radical mechanisms. Radical interceptors of chemical nature useful for food sterilization with high intensity electrons include spices and press juices of organs such as liver, brain and spleen. Tocopherol, esters of gallic acid and certain other polyphenols useful in this connection, may be combined with synergists such as ascorbic acid and citric acid for enhanced protective action.

Dose rate was shown to be of importance for the total chemical yield per unit dose. Consequently, high dose rates are useful for protection of flavor and color in foodstuffs.

Acknowledgments

The authors acknowledge with appreciation the contributions of Drs. E. L. Gaden and J. J. Henley, Department of Chemical Engineering, Columbia University. With their help, the dose rate experiments on tartrazine with gamma radiation from their one thousand curie Co-60 source, were carried out. The authors also wish to thank Messers. A. Astrack and H. A. Romney for valuable technical assistance in the experimental phases of this investigation.

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Application of Low-Cost, High-Capacity Classification to Thickening and Separation of Solids in the Food Industry[a]

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(Manuscript received June 6, 1952)

Theory, design, and operation of the liquid cyclone are discussed with reference to the major considerations in applying classification to the food industry to obtain thickening and elimination of solids from liquid suspension on the segregation of solids differing in specific gravity. Industrial operating examples are described to show the practical potential of the cyclone. Two cyclone modifications — the open-top and the liquid-liquid cyclone—are discussed and future applications indicated.

Undoubtedly classification has been practiced for several centuries in order to obtain maximum purity and recovery of valuable raw solid material. Probably the first miners of precious metals utilized unknowingly the concepts of classification to gain the sufficiently purified treasures they sought. Evidence of the large importance of this science today can be found by a brief observation of the mineral and coal industries where classification principles are a major if not dominant factor in practically all beneficiation methods prior to smelting and refining. Although classification has not gained the same importance in the food industry, it probably plays a prominent role in the theory of operation of some of the various raw cleaning methods.

Within the past 5 years, high-capacity, low-cost centrifugal classification has experienced a remarkable growth in the mining industries. Because of its special attributes and changing technology, it would also appear to have many applications in the food and agricultural fields. To better understand its utility, however, a brief review of classification theory is necessary.

CLASSIFICATION THEORY

The terminal or maximum settling velocity of a solid particle (velocity at equilibrium between gravitational, buoyancy, and frictional forces) is a basic concept of classification. Considering only unidirectional motion, it can be predicted by the equation

$$v_m = \left(\frac{4(\rho_s - \rho)_g D}{3\, f_{tp} \rho} \right)^{1/2} \qquad (1)^b$$

For particles coarser than $^1/_8$ inch and specific gravity differences between solids and suspension greater than 0.1, terminal velocities are sufficiently large to permit economic classification utilizing the force of gravity. As values decrease below these limits, the velocity diminishes rapidly making such classification increasingly difficult and expensive. Investigation of equation (1) would indicate that v_m for these particles can only be increased by either a decrease in fluid density or an increase in the driving acceleration, g. Naturally the former choice is quite limited if the solids must be processed in a liquid vehicle resulting in the forced selection of enlarging acceleration force in order to increase the classification or separation rate.

The acceleration, g, can be significantly advanced by use of a centrifugal force field wherein the fluid is given a curvelinear motion. Thus, for this case

$$\text{Acceleration} = \frac{V_t^2}{r} \qquad (2)$$

Mechanical centrifuges can now be purchased which will generate as much as 25,000 times the acceleration of standard gravity, while liquid cyclones are estimated to produce up to 10,000 times the acceleration of gravity. Obviously, settling velocities are given a tremendous increase, which greatly influences the economies of processing fine particles in a liquid suspension.

Classification possesses 2 fields of application. Thickening or recovery of the maximum amount of solids present in a suspension can be achieved by subjecting the particle to a sufficiently small counter fluid velocity permitting concentration in a dense underflow. Equation (1) or modifications thereof can be used to predict this separation rate. Classification can also be employed to separate solids of different specific gravities by utilizing liquid or suspension specific gravities and fluid velocities so that one solid will "float" or be taken off as an overflow product while the heavier "sinks" as an underflow product. A second basic expression is therefore needed to predict the particle size range (classification ratio) that can be separated by this method. If the size of the largest light particle is such that its settling velocity is equal to the smallest heavy particle, an upward velocity (radial velocity in the case of simplified centrifugal force pattern) of this same value would theoretically concentrate all light particles in the overflow and all heavy particles in the underflow. Mathematically this could be stated

$$\left[\frac{4(\rho_{sh} - \rho)_g D_h}{3\, f_{tm} \rho} \right]^{1/2} = \left[\frac{4(\rho_{sl} - \rho)_g D_l}{3\, f_{tl} \rho} \right]^{1/2} \qquad (3)$$

solving

$$\text{Classification Ratio} = \frac{D_l}{D_h} = \frac{(\rho_{sh} - \rho) f_{tl}}{(\rho_{sl} - \rho) f_{th}} \qquad (4)$$

For turbulent flow and particles of approximately the same shape factor or sphericity, f_t values are quite similar and for this important case

$$\frac{D_l}{D_h} = \frac{\rho_{sh} - \rho}{\rho_{sl} - \rho} \qquad (5)$$

If laminar flow exists, it can be proved that

$$\frac{D_l}{D_h} = \left[\frac{(\rho_{sh} - \rho)}{(\rho_{sl} - \rho)} \right]^{1/2} \qquad (6)$$

Naturally it is desirable to have a large classification ratio in order to process a wide size range in one unit. As seen from equations (5) and (6), the suspension density is extremely important in this regard, as the classification ratio approaches infinity as ρ approaches ρ_{sl}. The ratio remains at infinity if ρ is greater than ρ_{sl} and less than ρ_{sh}.

It should be emphasized that while the classification ratio indicates the maximum size range that can be treated by classification alone, it does not imply that the separation will occur in a particular classifier. Equation (1) must also be satisfied, and sufficient retention time must be incorporated in the classification chamber with the settling velocities in effect to permit the theoretical maximum separation. Thus, here again the close

[a] Presented at the Twelfth Annual Meeting of the IFT, Grand Rapids, Michigan, June 10, 1952.

[b] Nomenclature for all equations at end of paper.

specific gravity and fine particle sizes will present the most difficulty and augment the importance of centrifugal classification.

Two primary methods are available to obtain centrifugal classification—mechanical centrifuges and liquid cyclones. The former allows a relatively wide variation in retention time and can be designed to produce the highest centrifugal forces. Simultaneously, because of high velocity moving parts, metal strength factors, and close tolerances, initial and maintenance costs will be high. Furthermore, capacity per square foot of floor space will be significantly lower at an increase in power costs when compared with the liquid cyclone. Accordingly, mechanical centrifuges find their greatest application to ultra-fine classification of 5 microns and below or to cases where a maximum solid concentration product is necessary.

The liquid cyclone contains no moving parts and is simple in basic design. Initial, operating, and maintenance costs are therefore low while capacities range from 100 to 400 gallons per minute per square foot of cross sectional area. Only conventional fluid pumps are used to furnish the energy for the creation of centrifugal force which further reduces process complexity and cost. While classification down to particle sizes of 10 microns has been achieved, food applications would probably be limited to about 75 microns because of usual small density differences between fluid and solid. Its main disadvantage compared with the centrifuge other than the higher bottom size of classification is the more dilute solids product it produces (probably limited to 55-60% by volume of solids).

Centrifugal classification for thickening and separation should be of significant importance to the food industry for the following reasons:

1. Particle sizes usually encountered are relatively small; (i.e., less than ½ inch).
2. Many food processing steps are executed in a liquid vehicle which may necessitate at least a thickening step.
3. Because many of the materials processed are organic in nature, a specific gravity difference usually occurs between solids to be separated. However, these differences are generally quite small, making gravitational classification costly or economically impossible.
4. Agricultural and synthetic organic products usually possess specific gravities approaching very closely that of the liquid process vehicle (generally water). Centrifugal force may be desirable to obtain a rapid classification.
5. In many instances, water will be intermediate in specific gravity between the solid to be separated affording a cheap fluid presenting an infinite classification ratio. In other cases only a small amount of ultra-fine solids (such as starch) or soluble salts need be added to obtain an intermediate specific gravity suspension.
6. Process costs, inventories, and floor space requirements can be significantly lowered while product purities and process simplicity can be increased when compared with conventional classifiers.

Because of its recent innovation and appealing low cost features, the paper will be confined to the theory, operation, and application of the liquid cyclone to the food industry.

CYCLONE DESCRIPTION AND THEORY[b]

The liquid cyclone in appearance consists of a cylindrical section mounted on the base of a conical section. An industrial unit, the Dorrclone *(9)* is illustrated in Figure 1. The feed enters tangentially at the cylindrical section and outlets are provided at either extremity of the cyclone centerline. The result of this tangential entry is a free vortex within the cyclone. This is composed of a double-spiral flow pattern. The outer spiral moves towards the apex of the conical section, which is commonly called the underflow. The inner spiral possesses the same rotation, but is directed towards the vortex finder or overflow tube located in the cover plate at the centerline of the cylindrical section. A secondary flow pattern also exists. This is made up of radial migration of fluid into the inner spiral at all points between overflow and underflow ports. Because of its simple design, the cyclone can be constructed of almost any material and can be completely rubber-lined as desired.

Particles heavier than the fluid vehicle and of sufficient size will be thrown to the walls by the centrifugal force of the tangential velocity component and thus travel in the outer spiral to the cyclone underflow. The smaller particles below the classification point will be concentrated to a lesser extent, and accordingly, report in increasing percentages to the overflow as size decreases.

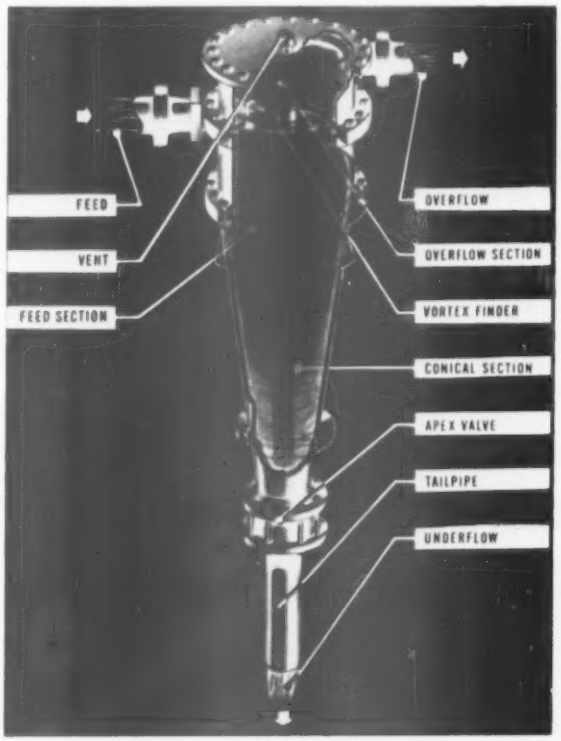

Figure 1. The Dorrclone.

Particles lighter than the carrying vehicle will undergo an acceleration towards the center of the centrifugal force field, and therefore, migrate to the inner spiral, which discharges at the overflow. It has been found the "float" material can be separated to a finer particle size than "sink" material at the same driving force because radial velocity components tend to promote this segregation.

For an ideal frictionless fluid in a free vortex, as in a cyclone, the torque or rate of change of angular momentum for a fluid particle would be constant.

$$\text{Torque} = MV_t r = \text{constant} \qquad (7)$$

A fluid particle moving through the cyclone would therefore exhibit the following relationship:

$$V_t = \frac{K'}{r} \qquad (8)$$

For a real fluid it has been found

$$V_t = \frac{K''}{r^n} \qquad (9)$$

where the exponent, n, probably lies between 0.6 and 0.8 for liquids such as water. However, the tangential velocity cannot attain infinity at the cyclone centerline as predicted by equation (9). Rather it is believed that maximum tangential velocity

[b] Technical background in much greater detail may be found by consulting the references *(1-9)* given at the end of this article.

occurs at the outer radius of the inner spiral and then decreases in almost a straightline manner to a zero value at the centerline.

As centrifugal force is proportional to V_t^2/r, the force will increase rapidly as the fluid particle migrates towards the inner spiral. The outer radius of the inner spiral is approximately equal to the overflow radius which permits the maximum centrifugal force at the most important point. "Sink" particles must travel through this zone before they can be discharged to the wrong port (the overflow).

The final significant item concerning cyclone flow pattern is its uniformity. The tangential and radial velocity components are practically constant for a radius within the cyclone at any plane normal to the centerline between overflow and underflow nozzles. The remarkable symmetry, high centrifugal force, and optimum location of critical radius contribute towards a sharp classification at a fine particle size.

BASIC DESIGN AND OPERATING EQUATIONS AND CORRELATIONS

Equations and correlations are necessary to predict cyclone energy requirements, design factors, fineness of classification, and probable separation between solids of different specific gravity. Armed with this data, it is possible to completely design and specify a cyclone process for any suitable application. Although the literature contains a large amount of this necessary information, the most basic material will be briefly considered for a better understanding of cyclone applications.

Capacity or energy requirements for a liquid cyclone can be predicted by the following equation:

$$\frac{Gpm}{\sqrt{F}} = K(eb)^{0.9} \qquad (10)$$

The proportionality constant, K, is primarily a function of percent of feed volume reporting to the underflow, cyclone included angle, percent of cyclone radius covered by feed and overflow nozzles, and feed solids concentration. Values of K will be found in the literature, and generally lie between the relatively narrow range of 5.5 to 6.5. Overflow diameter will usually be from 100 to 150% of the inlet diameter, while the *2* nozzles will consume from 40 to 70% of the cyclone radius. As 40 feet of fluid pressure drop will give almost maximum separation efficiency for any cyclone, it can be easily proved that cyclone capacity will be a minimum of 200 g.p.m./ft.^{2} of cross sectional area for these values. This is by far the highest capacity factor for any classifier.

A second basic expression has been developed to determine the extent or fineness of classification which can be achieved in any cyclone. Thus, it furnishes a method of determining critical cyclone design dimensions. The equation is of particular importance in applications to solid elimination or thickening when maximum recovery of such solids down to a certain size must be obtained from a feed slurry. The equation predicts the particle size expressed as equivalent diameter (diameter of sphere of same specific gravity and settling velocity) that will report in equal weight percents to both overflow and underflow streams.

$$50\% \text{ particle size, microns} = \mu = \frac{C(eb)^{1.75}}{(G.p.m.)^{0.75}}\left(\frac{1.73}{\rho_s - \rho}\right)^{0.5} \qquad (11)$$

The proportionality constant, C, is again a function of minor design factors—primarily included angle and percent of cyclone radius consumed by overflow and inlet nozzles. For a 15° included angle cyclone the constant value is equal to 81. As particles finer than the 50% point will report primarily to the overflow, and those coarser will report almost 100% to the underflow, the value represents an economic limit for recovery or thickening.

It should be pointed out that greater deviations from predicted results are experienced in this phase than with energy requirements, capacities, and separation between "float" and "sink" materials. This is due primarily to the larger number of influencing operation variables such as particle shape, size distribution, and feed solid concentration. Other operating results from the mining industry will be found in the literature.

The separation of solids of different specific gravity is attained in the cyclone by use of an intermediate specific gravity liquid which will "float" the lighter material and allow the heavier particles to sink. By feeding the resultant suspension to a cyclone, the separation rate is greatly accelerated. The "float" solids are recovered in the overflow and the "sink" in the underflow. Good separation has been obtained on particles as fine as 100 mesh and differing in specific gravity by as little as 0.01.

Recovery of "float" and "sink" solids in the appropriate streams (and thus individual product purity) was found to be primarily a function of feed volume split to the cyclone underflow, liquid-solid specific gravity difference, and particle size. However, due to the complexities of interactions of certain variables, it was found advantageous to present the expected recovery values in graphical form. Figures *2A*, *2B*, and *2C*

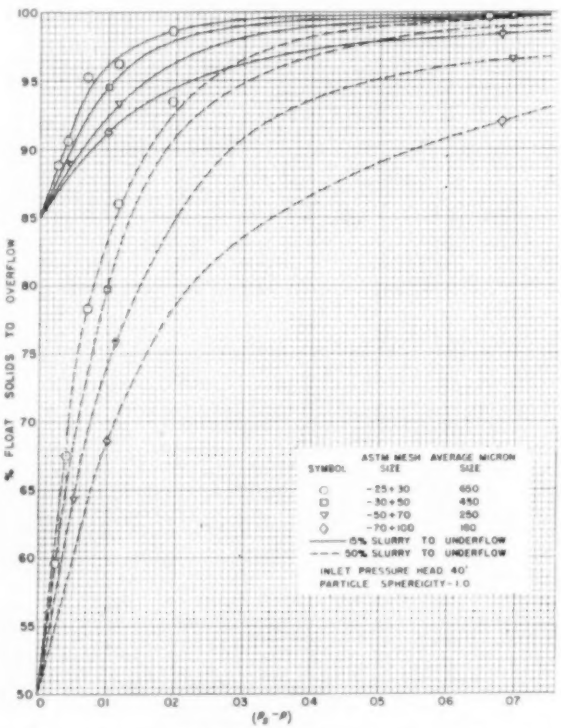

Figure 2A. Percent float solids to overflow vs. solid-liquid specific gravity difference with parameters of particle size and percent slurry to the underflow.

indicate percent recovery of "float" solids in the cyclone overflow as a function of liquid-solid specific gravity difference with parameters of percent of feed volume reporting to the underflow and particle size. The graphs permit the prediction of recovery per cyclone for particle sizes from 25 to 100 mesh U. S. Standard and liquid-solid specific gravity differences from 0 to 0.075.

Figure *3* is a similar plot for "sink" material with the dependent variable being percent recovery of "sink" solids in cyclone underflow. However, in this instance particle size between 25 and 100 mesh was not found to be significant, and results could be indicated on one graph. "Sink" solids recovery can be estimated from Figure *3* for 25 to 100 mesh particle size and 0 to 0.045 solid-liquid specific gravity difference.

There are certain restrictions on both Figures *2* and *3*.

1. All data were obtained on spherical particles. However, non-spherical particle estimates can be made by measuring the gravitational settling velocity of representative samples of the various particle sizes present, and calculating the sphere diameter of the same settling velocity. This can be done quite easily in any laboratory and has yielded reliable results by comparison with actual industrial data on non-spherical particles.

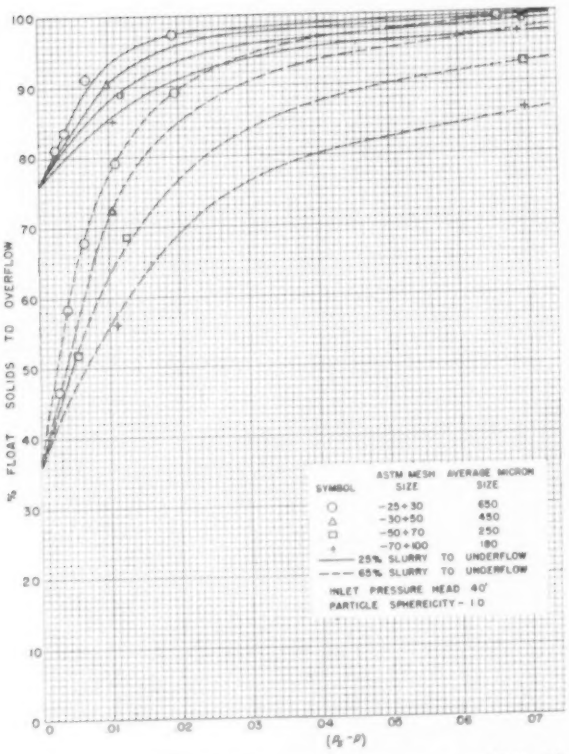

Figure 2B. Percent float solids to overflow vs. solid-liquid specific gravity difference with parameters of particle size and percent slurry to the underflow.

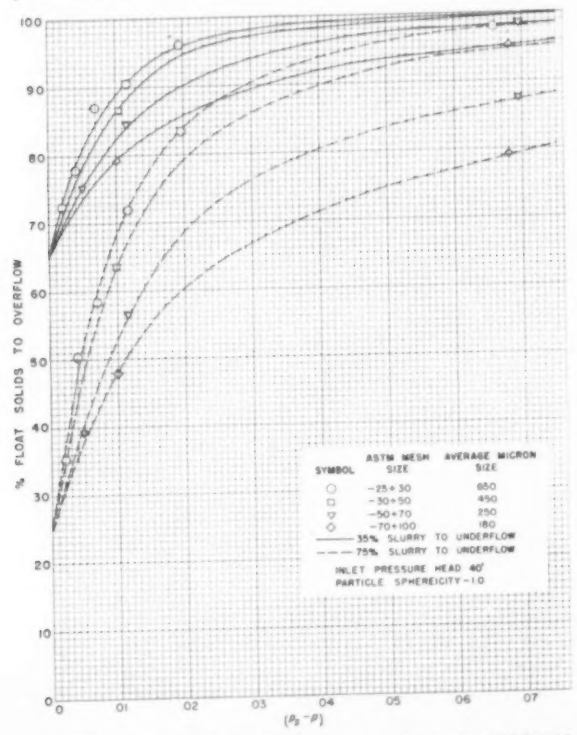

Figure 2C. Percent float solids to overflow vs. solid-liquid specific gravity difference with parameters of particle size and percent slurry to the underflow.

2. Cyclone pressure drop of 40 feet of fluid is implied throughout the curves. Larger values, while giving greater cyclone capacity, will generally exhibit only a slight increase in recovery.

3. Solid concentration in the feed slurry was maintained at less than 4% for flat, paper-thin particles up to 8% maximum for spheres. Above these values recoveries will decrease slightly although they will usually not be appreciable until values of 10 to 15% solids are experienced.

4. Cyclone included angle is 15°. Larger values would tend to decrease recoveries while smaller angles should exhibit a slight increase.

5. Cyclone diameter was 3 to 9 inches.

Further experimental work indicated that equal back pressures on overflow and underflow parts did not decrease recovery. Additionally, it was proved that recovery of each particle size is independent of the amount of cyclone stages as the recovery of one size in the second, third, or fourth units will be as predicted from Figures 2 and 3. Accordingly, the flow sheet of Figure 4 is possible wherein stage separation is utilized with only one pump. Each stage must be designed to exhibit the optimum flow rate, volume split, and pressure drop as well as equal overflow-underflow pressures.

By use of Figures 2 and 3, it is possible to calculate final product purities and recoveries, number of separation stages required, optimum volume splits, and desirable liquid specific gravity if a fluid other than water is to be used. Because of the recycle stream a trial-and-error solution to obtain the above factors is necessary although only simple material balances are involved. Furthermore, there are certain generalities which will considerably reduce the number of attempts that must be made to establish optimum conditions. Volume split to the underflow for the "float" refining branch (upper branch of Figure 4) will normally run 60 to 75%, 15 to 35% for the "sink" refining branch, and approximately 50% for the feed cyclone. Liquid specific gravity will generally be quite close to the "float" specific gravity due to its greater ease of separation. These short cuts facilitate the calculations, and a suggested approach to the solution method will be found in the literature.

It is interesting to note about 4 cyclone stages of separation could be operated on one conventional feed pump as indicated in Figure 4 if 40 feet of fluid pressure drop is used across each stage. However, most separation problems will require only one to two stages.

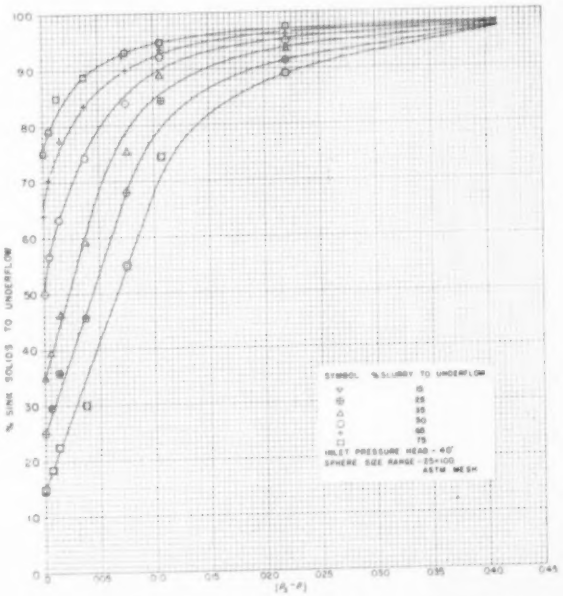

Figure 3. Percent sink solids to underflow vs. solid-liquid specific gravity difference with parameters of percent slurry to the underflow.

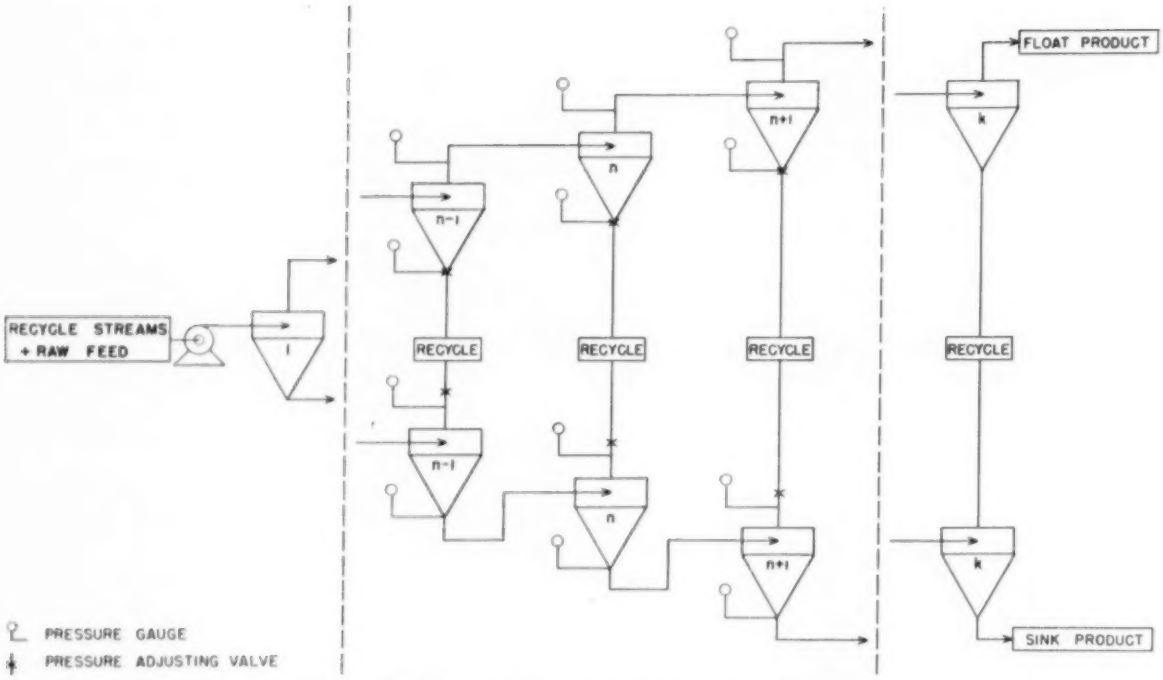

Figure 4. Multiple cyclone arrangement for stage solid separation.

Finally, it should be cautioned that many applications must naturally be tested under pilot plant or single stage tests to predict actual operating results to insure success. The prediction methods outlined, however, will definitely indicate the potentiality of any application, and decrease the amount of testing that must be done. Furthermore, due to the low cost of the equipment and its high capacity, test expense will be nominal and the units may be utilized in the full-scale operation.

APPLICATIONS TO THE FOOD INDUSTRY

Although the installations of liquid cyclones have been numerous and varied in other fields, applications to the food industry are still in the experimental stage. Thus, it will be necessary to indicate results on similar types of materials and various methods of use to date in order to display its process possibilities. These examples can be divided into the two categories of classification of "sink" solids down to a bottom particle size and separation of solids of different specific gravity.

Classification. Probably the major use of liquid cyclones has been the thickening and recovery of "sink" solids from water suspensions. Undoubtedly, this has resulted in the recovery of hundreds of thousands of tons of coal and ore that formerly were discarded because of uneconomical process costs *(2, 5)*. In such applications the cyclone will process 150 to 400 gallons per minute of slurry and up to 20 tons of solids per hour per square foot of cross section, use a feed pressure range of 3 to 50 pounds per square inch and cyclone diameters of 3 to 36 inches. Table 1 indicates representative results on a 9-inch diameter, 20° included angle cyclone with varying specific gravity solids, feed pressures, and feed solid concentrations. In all cases, a maximum recovery of "sink" solids in the cyclone underflow at a low dilution was required.

TABLE 1
Typical results—nine-inch cyclone
Elimination from suspension—industrial solids

	Coal	Coal	Coal	Sand
Solid Specific Gravity	1.5	1.5	1.45	2.73
Feed				
Pressure—P.s.i.g.	11½	48½	6	3½
Flow Rate—G.p.m.	115.6	82.3	172.8	74.6
Solids Rate—Tons/Hr.	1.15	3.12	8.85	7.20
Solid Concentration—Wt. %	3.88	14.1	19.43	31.1
Size Analysis—Wt. %				
+100 Mesh U. S. Std.	76.3	82.1	66.4	86.5
100 × 200	3.2	3.8	7.4	8.8
−200	20.5	14.1	26.2	4.7
G.p.m./Ft.² Cross Section	261	186	390	169
Tons Solids/Hr./Ft.² Cross Section	2.60	7.05	20.0	16.3
Overflow				
Flow Rate—G.p.m.	108.8	63.8	131.2	50.6
Solids Rate—Tons/Hr.	0.19	0.21	1.70	0.13
Solid Concentration—Wt. %	0.68	1.3	5.05	1.02
Size Analysis—Wt. %				
+100 U. S. Std.	0.0	0.0	0.5	0.0
100 × 200	2.1	0.0	4.5	0.0
−200	97.9	100.0	95.0	100.0
Underflow				
Flow Rate—G.p.m.	6.8	18.5	41.6	24.0
Solids Rate—Tons/Hr.	0.96	2.91	7.15	7.07
Solid Concentration—Wt. %	45.1	48.4	58.6	68.0
Size Analysis—Wt. %				
+100 U. S. Std.	91.2	88.0	82.2	88.1
100 × 200	3.4	4.1	8.0	9.0
−200	5.4	7.9	9.8	2.9
Feed Solids Recovery—Wt. %				
+100 U. S. Std.	100.0	100.0	99.9	100.0
100 × 200	89.3	100.0	88.3	100.0
−200	22.1	52.4	30.3	61.2

It will be observed in Table 1 that all plus 100-mesh material could be concentrated in the cyclone underflow for the solid specific gravity range of 1.45 to 2.73. Furthermore, recovery of the 100 × 200 mesh fraction ranged from 88.3 to 100% even though feed pressures

as low as 3¼ pounds per square inch were employed. Capacities per square foot of cross section fall within the ranges quoted above.

The flow sheet of Table 1 merely consists of a conventional centrifugal slurry pump feeding the cyclone, and both overflow and underflow streams discharging at atmospheric pressure. This simple process can also be employed through correct cyclone design to efficiently separate a coarse product from unwanted fines. To show the extent to which cyclone design has been developed as well as the application of fine particle size elimination from coarser solids, a recent industrial flow sheet is pictured in Figure 5. In this instance, a fine clay material had to be removed from chemical sand to maintain a high-product purity. The installation was complicated, however, by a very high feed solids concentration (45% solids), high flow rates, low pressure heads, and demands for process simplicity and practically 100% recovery of plus 200-mesh solids. To satisfy these requirements, two 36-inch diameter cyclones are employed to remove the bulk of the sand in the first stage at a low feed pressure of 3⅞ pounds per square inch. The overflow from the first stage discharges to a pump sump where it is fed to two 30-inch cyclones at 4½ pounds per square inch pressure to recover the remaining sand. The lower feed dilution in the secondary units and their particular design permits a lower classification point. To obtain sufficient removal of clays from the first stage underflow product, fresh water is added tangentially to these cyclones in the conical section. Clay-bearing water in this region is replaced by clear water increasing clay elimination to 99.1%. Without this step, clay elimination would only be 82.6%.

Operating results with this process are given in Table 2 and indicate the extremely high solids and slurry rate processed in each unit at the low feed pressures. Plus

TABLE 2

Industrial application of cyclones
Classification at specified particle size
(Classification point—approximately 30 microns)
Washing of chemical sand

	Stage I Per 36-inch cyclone	Stage II Per 30-inch cyclone
Feed		
Pressure—P.s.i.g.	3⅞	4½
Flow Rate—G.p.m.	967	686
Hydraulic Water Rate—G.p.m.	65	0
Solids Rate—Tons/Hr.	151.2	18.9
Solids Concentration—Wt. %	45.0	10.5
% Clay in Solids	3.0	23.8
Overflow		
Flow Rate—G.p.m.	686	652
Solids Rate—Tons/Hr.	18.9	3.8
Solids Concentration—Wt. %	10.5	2.54
% Clay in Solids	23.8	96.3
Underflow		
Flow Rate—G.p.m.	341	34.0
Solids Rate—Tons/Hr.	132.3	15.1
Solids Concentration—Wt. %	77.9	78.0
% Clay in Solids	0.03	0.9
% Elimination of Clay to Overflow	99.1	96.5
Overall +200 Mesh Recovery in Underflows	99.9	
Overall to Clay in Underflow Products	0.12	

200-mesh recovery averages 99.9% with a 0.12% final clay content. In this application sand recoveries well exceeded previous experience, clay content was approximately ½ the former value, wash water requirements were cut by 90% and labor personnel reduced by 50%. This is an indication of the economical advantages of cyclone classification compared with conventional gravitational methods. Other similar installations where sufficient pump pressure is available have obtained further process simplicity by directly connecting the first stage overflow to the second stage feed.

Results on material similar in nature to that encountered in the food industry can also be cited. The

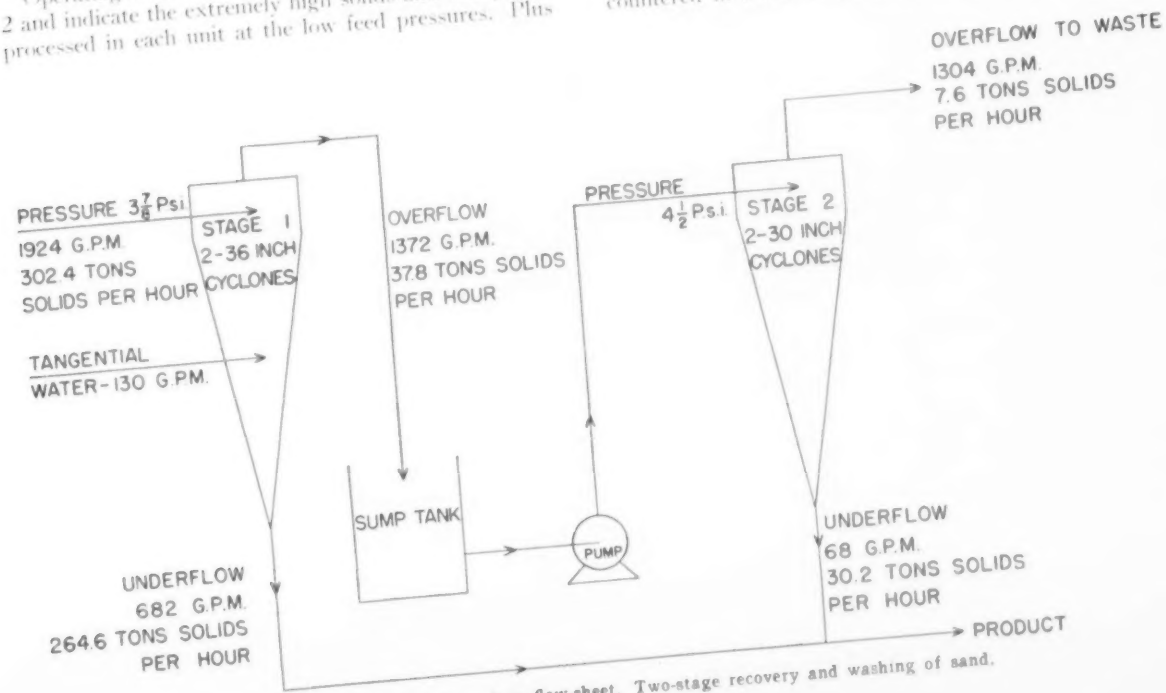

Figure 5. Industrial cyclone flow-sheet. Two-stage recovery and washing of sand.

cyclone has been utilized in the production of paper stock to separate small pieces of bark and grit from pulp suspensions to obtain the required fiber purity. Very large flow rates must be handled with a surprising degree of refuse elimination. Disc-like particles are involved causing disadvantageous shape factors, and fiber recoveries must be very high. The first application to the paper industry is recorded in U. S. Patent No. 2,377,524 by Samson *et al.* While the first cyclones were relatively small in diameter and capacity, recent tests on larger 5-inch units at feed rates of 55 g.p.m. with 20 pounds per square inch pressure drop have given good results. Larger diameter cyclones and feed rates are now being tested with the hope of obtaining further process simplicity and lowered initial and operating costs at an acceptable classification efficiency.

In these applications, the paper fiber is not concentrated by the centrifugal force field while the bark and grit act as "sink" material. The limit of efficient classification appears to occur between 100 and 200 mesh (148 to 75 microns) with the "sink" solids ranging in specific gravity from just slightly heavier than water to 2.7. It is apparent that material of similar specific gravity and particle shape will be encountered in the food industry implying the probable application of the cyclone.

Tests have been conducted at Northwestern University on ground vegetable pulp in an attempt to separate it from extreme fines in a water suspension. A 9-inch diameter cyclone was employed at a feed pressure of 18 pounds per square inch. A feed rate of 155 g.p.m. resulted, and the overflow was screened at 100 mesh. Only a very small amount of plus 100 mesh "sink" material was found in this stream; and it was estimated that 100% recovery of "sink" solids occurred down to 80 mesh (175 microns) in the cyclone underflow. Furthermore, the vegetable pulp was delivered as a thickened product occupying a small volume percent of the original feed. An additional advantage of the cyclone in this adoption was the markedly reduced effect of viscosity. The feed slurry was appreciably more viscous than the water vehicle due to the nature of the extreme fines. As high shearing forces are present in the cyclone, particles are considerably freer to migrate to the correct stream, and flocculation can be entirely destroyed.

From the results discussed above, it seems reasonable to surmise that thickening and recovery from suspensions of solids found in the food industry can be achieved with liquid cyclones at economic flow rates and feed pressures. Bottom size of classification should be at least 60 to 100 mesh. Typical installations may involve elimination of solids from process waters, preliminary thickening of material prior to final mechanical dewatering, performance of a sizing operation to separate fine solids from coarser products, and elimination of refuse particles from food suspensions. A more concrete example is the research now being conducted to separate corn starch from gluten after milling.

Separation between solids of different specific gravity. There are probably a number of applications of the liquid cyclone to the separation of solids in the food industry due to naturally occurring specific gravity differences in organic materials. Furthermore, as pointed out earlier, solid specific gravities lie fairly close to 1.0. Thus, water with or without small amounts of weighing agents can be used to achieve a "float-sink" separation. The application of cyclones to the separation of corn germ from hulls and fiber is now being tested. Other potential examples are the elimination of imperfect food solids (such as immature or dried peas) from the acceptable product; the separation of different crystallized solids; the classification of seeds according to specific gravity to eliminate weeds and obtain greater yields; the separation of fine chaffs from seeds or fibers. Fortunately, there are sufficient industrial installations on materials similar to those found in the food industry to aid in evaluating the process.

The liquid cyclone has been used to separate a high-value pharmaceutical material from certain seeds. Particle sizes range from approximately $\frac{1}{16}$ to $\frac{1}{4}$ inch for both "float" and "sink" solids. The pharmaceutical material, which is actually an impurity in the seed, exhibits maximum specific gravity of 1.17 although a small percentage possesses values as low as 1.0. On the other hand, the seeds are 85% heavier than 1.30 and only undeveloped seeds are lighter than 1.17. Because of the relatively large particle sizes and appreciable specific gravity difference between the 2 categories of solids, a one-stage separation process was utilized. A 9-inch diameter cyclone was employed, and correct liquid specific gravity was obtained by blending carbon tetrachloride and benzene. Operating results are given in Table 3.

TABLE 3

Cyclone operating results
Separation of pharmaceutical solids from seeds

	Feed	Overflow	Underflow
Pressure—P.s.i.g.	25.5	0	0
Liquid Specific Gravity	1.20		
Volume Rate—G.p.m.	189.8	182.2	7.6
Solids Rate—Pounds/Hr.	3000	610	2390
Solid Concentration—Wt. %	2.62	0.56	53.0
Analysis of Solids			
1.213 "Float"—Wt. %	20.2	99.5	Tr.
1.213 "Sink"—Wt. %	79.8	0.5	99.9+
Distribution of Solids			
1.213 "Float"—Wt. %	100.0	100.0	0.0
1.213 "Sink"—Wt. %	100.0	0.15	99.85

Recovery of "High-Value" Pharmaceutical Feed Solids in Overflow = 100%.
Purity of "High-Value" Pharmaceutical Overflow Solids = 97 + %.

Practically a complete separation of "float" and "sink" material is obtained as indicated by the analysis of underflow and overflow streams. The pharmaceutical material is 100% recovered in the overflow at a 97 + % purity by weight, the remainder being immature seeds whose specific gravity is less than 1.20. A solid rate of 3000 pounds per hour was in effect at the time the data were taken. Rates as high as 4 tons per hour have been used, however, without loss in recovery or purity.

The installation was particularly noteworthy, as it represented the first successful continuous process to achieve separation between the two materials. Formerly, costly hand methods were used to obtain a product of less purity with significant pharmaceutical losses. Furthermore, initial and operating costs are low, the process is simple, and a salable purified seed product is obtained.

A second industrial installation illustrates the application of cyclone stage separation. The raw material consists of a ground seed material containing a valuable chaff and a refuse kernel. The important physical properties of the two solids are listed below:

	Sink Material Valuable Chaff	Float Material Refuse Product
Composition by Weight	85%	15%
Specific Gravity	1.270 ± 0.005	1.200 ± 0.030
Particle Shape	Concave Discs	Needles
Size Range—Microns	830 to 0	500 to 0
Average Equivalent Spherical Diameter—Microns	340	300

Observation of the above data indicates a formidable separation problem. Particle sizes are fine with appreciable amounts below 100 mesh, the shape factors are very poor, and specific gravity differences between solids as small as 0.035 are present. Added to this, "sink" product purities of 99.2% are demanded with recoveries of at least 95%.

Calculations were made from the curve of Figures 2 and 3 which indicated two stages of separation were necessary to meet the requirements on purity and recovery. A two-stage cyclone pilot plant employing only one pump similar to Figure 4 was constructed with a 5-inch feed unit, a 4-inch "sink" refining cyclone, and a 3-inch "float" refining cyclone. Optimum liquid specific gravity was determined to be 1.235 to 1.240. A value of 1.238 was used in the pilot plant tests, the results of which will be found in Table 4. Included in the table for comparison are the calculated results based on the methods previously presented.

Observation of Table 4 indicates good agreement between calculated and actual values. Undoubtedly the chief reason for any deviation is the assumption of the equivalent spherical diameter for each solid. Because the size range is actually 20 mesh by zero, this method cannot be too precise. However, a rigorous analytical treatment would require individual examination of each significant size fraction.

The industrial installation employing larger cyclones duplicates the final results of Table 4. Product purities run 99.8% with recoveries of 98 to 99%. The cyclone method again was the first successful, completely continuous process on this material. Formerly, batch methods utilizing manual labor were able to achieve product purities of only 99.2% with valuable solid losses of 4%. Additionally, such operation necessitated a thorough exhaust system in order to eliminate toxic organic vapors from the working area. As a consequence, exceedingly large quantities of expensive volatile organic liquids were lost to the atmosphere. With the cyclone installation, filters and driers are completely in closed circuit with a condensing refrigeration system to recover the evaporated liquids. These savings will more than pay for the installation in the first year. Finally, the entire process is automatically controlled to yield labor savings.

A second pilot plant test has just been completed on the separation of anion and cation resins used in mono-bed ion exchange work. This step is necessary before regeneration of the resins can be accomplished. Physical properties of the two test solids are indicated below:

	"Sink" Resin	"Float" Resin
Specific Gravity	1.074	1.046
Average Particle Size—Microns	350	495
Particle Shape	Beads	Beads

While the particle sizes are approximately equal to those in the previous problem on the separation of fine chaff from seed kernels, specific gravity difference between solids is only 0.028. Thus, the proper segregation is even more difficult to obtain.

A 50-50 mixture by weight of the two resins was used in the tests with two stages of cyclone separation and a liquid specific gravity 1.058. "Float" and "sink" product purities were 99.55% and 97.9%, respectively, while recoveries of each category in the appropriate stream were 97% and 99.7%, respectively. Calculated results again corresponded closely with actual operating data.

TABLE 4
Industrial cyclone stage separation
Pilot plant data

	Feed		Overflow		Underflow	
	Calculated	Actual	Calculated	Actual	Calculated	Actual
Stage 1—5-Inch Cyclone						
Pressure—Feet of Fluid	81.3	79.5	44.0	49.2	54.2	51.0
Flow Rate—G.p.m.	13.4	13.4	7.6	7.6	5.8	5.8
Solid Concentration—Wt. %	3.0	2.93	1.20	1.35	4.60	4.99
% of "Sink" Solids Recovered in Underflow					96.9	91.1
% of "Float" Solids Recovered in Overflow			95.8	93.3		
Stage 2—"Float" Refining Branch—3-Inch Cyclone						
Pressure—Feet of Fluid	44.0	49.2	0	0	0	0
Flow Rate—G.p.m.	7.6	7.6		2.4		5.2
Solid Concentration—Wt. %	1.20	1.35		2.29		0.66
% of "Sink" Solids Recovered in Underflow					97.6	89.7
% of "Float" Solids Recovered in Overflow			88.8	87.8		
Stage 2—"Sink" Refining Branch—4-Inch Cyclone						
Pressure—Feet of Fluid	54.2	51.0	0	0	0	0
Flow Rate—G.p.m.	5.8	5.8		4.0		1.8
Solid Concentration—Wt. %	4.60	4.99		1.98		11.25
% of "Sink" Solids Recovered in Underflow					93.8	73.8
% of "Float" Solids Recovered in Overflow			97.3	91.7		

Final "Sink" Product Purity Weight % = 99.9% Calculated, 99.8% Actual
Recovery of "Sink" Material as Product = 99.9% Calculated, 98.6% Actual

From the above three examples, it is evident that product purities and recoveries of 97 to 100% can be obtained on solids differing as little in specific gravity as 0.02 and as fine as 100 mesh in a maximum of 2 cyclone stages. If higher purities and recoveries are demanded or more adverse solid physical properties are encountered, further stages can be added to meet specifications.

Special cyclone modifications. Two modifications of the cyclone are worthy of mention as they indicate further applications of this economical centrifugal force equipment. Both are presently in the experimental stage which will limit their presentation to brief discussions.

The vexing problem of the separation of rat feces from corn was suggested as a possible application of the liquid cyclone. Both solids are approximately the same size prohibiting screening as a segregation method. The rat feces as well as the corn are heavier than water, but there is sufficient natural oils and porosity present in the majority of dried feces to resist wetting and allow the inclusion of air. Thus, most of the pellets will float on water. However, even the centrifugal force field of the liquid cyclone at low operating pressure is sufficient to expel the air from the feces and thoroughly wet each pellet. The feces then act as a "sink" particle and report to the underflow with the corn.

To eliminate the above result, a 30-inch test cyclone was constructed without a cover plate on the cylindrical section to allow lower centrifugal force fields. Water was pumped to the feed nozzle through a venturi to permit the entrance of the dried corn and rat feces at this point. A normal cyclone underflow was utilized while the overflow consisted of a peripheral weir discharge at the top of the cylindrical section. Four advantages were derived from this construction.

1. Feed pressures were maintained at about 1 pound per square inch to obtain power economies.

2. Rat feces (primarily "float" particles) could migrate vertically and escape the higher centrifugal force field near the centerline.

3. Retention time of the corn in the water was very small allowing only a negligible increase in moisture content of the kernels.

4. Because of the cyclone flow pattern, it would be practically impossible for a corn particle to circulate within the cyclone for any length of time preventing the possibility of bacterial action.

Tests to date have utilized flow rates as high as 116 g.p.m., and it is estimated that the value can be doubled after further enlargements on the underflow diameter are made. Solid concentrations as high as 15% (4.3 tons per hour at 116 g.p.m.) did not harm the separation. Eighty percent of the rat feces were recovered in the overflow with no loss of good corn. Only stunted and imperfect corn kernels reported to the overflow stream. The feces lost to the underflow averaged at least 95% "sink" and were primarily pellets that did not originally "float." Retention time of the corn in the cyclone was found to be less than 10 seconds.

Another research investigation is directed towards the use of the cyclone to separate immiscible liquids. The first phase of the study has now been completed, and it has been proved that segregation is possible. In the initial work a 3-inch cyclone was employed for all tests with a liquid-liquid specific gravity difference of 0.11. Feed pressures ranged up to a maximum of 20 pounds per square inch gage, and observations were made on the influence of feed composition and feed volume split to the underflow upon separation. Figure 6

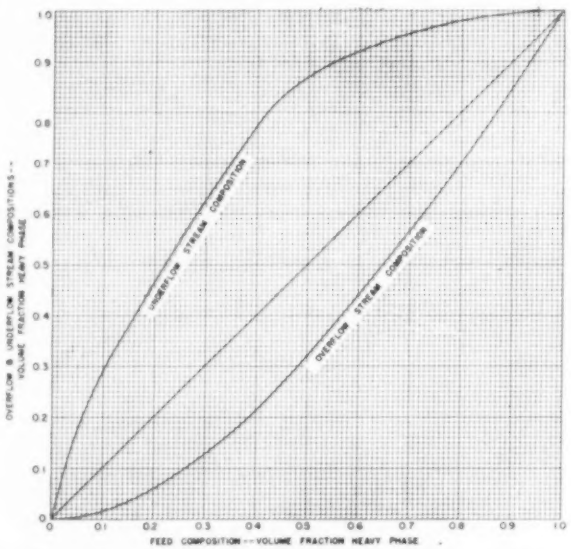

Figure 6. Experimental liquid-liquid cyclone separation. Overflow and underflow composition vs. feed composition.
Cyclone diameter—3 inches
Volume split to underflow—30%
Cyclone pressure drop—20 p.s.i.g.

is exhibited to indicate typical results obtained in this initial work. Overflow and underflow stream compositions are plotted as a function of feed composition, all expressed as volume fraction of heavy phase. If no concentration of phases occurred, the 45° line included in Figure 6 would apply to both underflow and overflow streams. It is immediately apparent that significant segregation was obtained as the underflow was decidedly richer in the heavy phase than the overflow. Certain conclusions were reached at the finish of the first phase of this work:

1. Complete separation of liquids is not possible in one cyclone. However, stage separation can be used to obtain any desired product purity. Furthermore, intermediate pumps between stages are not necessary.

2. Initial data indicated that the optimum pressure drop per cyclone will again be about 40 feet of fluid as further increases will yield only slight increases in separation. It will probably be more economical to use the excess pressure by adding more stages with their higher separating power.

3. Optimum feed volume splits to the underflow will be a function primarily of feed composition.

4. Energy requirements and capacity for the liquid-liquid cyclone will be very similar to those of the liquid-solid cyclone at the same operating and design parameters.

5. Some unstable emulsification may tend to take place in the cyclone. Separation is not effected unless the emulsion becomes relatively stable. Undoubtedly, emulsification will be one of the major problems in most applications.

The chief aim of this work is to apply cyclone separation to liquid-liquid extraction. During the course of the investigation it was observed that a complete equilibrium contact stage in liquid-liquid extraction can be obtained by the intimate mixing given the two phases in a centrifugal pump. This, naturally, simplifies the flow sheet, as the pump is used for a dual purpose. The predicted process is illustrated in Figure 7.

The main advantages of cyclone liquid-liquid extraction and separation are:

1. Very high capacity compared with the packed towers or mixing and separating tanks used today.

2. Inventory of liquid phases will be only a small fraction of present industrial methods.

3. Floor space and head room should be materially decreased.

Further work is now in progress utilizing larger cyclones with the purpose of thoroughly investigating all variables. It is anticipated that better separation will be obtained with the new units, as certain modifications have been made. Finally, with the completion of this work a complete liquid-liquid extraction pilot plant will be constructed to test the economic feasibility of the process.

SUMMARY

The potential importance of classification to the feed industry to obtain thickening and elimination of solids from liquid suspension or the segregation of solids of differing specific gravity has been discussed and emphasized. Several reasons to support this contention were mentioned, the major ones being

1. The process is simple and economical.

2. Correct classification exhibits a high efficiency of separation.

3. Natural or synthetic organic materials generally exhibit at least small differences in specific gravity between the various solids found in mixtures. Separations based on specific gravity can yield products of exceptional purity if properly applied.

4. Many of the materials encountered in the food industry possess specific gravities closely approximating those of water. Thus, this economical fluid with or without weighing agents can be used as the carrying vehicle.

Liquid cyclones have exhibited an exceptional growth within the first five years of their industrial use in this country. The reasons for the phenomenal rise of this classifier are several.

1. They yield the finest classification point of any industrial classifier with the exception of the considerably more expensive centrifuge.

2. They possess by far the highest capacity of any classifier, ranging up to 400 g.p.m. per square foot of cross section.

3. Initial investment and maintenance costs are the lowest of any classifier. With the development of low pressure cyclones, power costs can be comparable to or less than gravitational classifiers.

4. Floor space and head room is minimized.

5. Process simplicity is increased.

6. Inventories of materials in process are decreased.

7. The classified solids are delivered in a concentrated suspension.

For these same reasons the liquid cyclone should be of special use to the food industry.

Theory, design, and operation of the liquid cyclone has been discussed with respect to major considerations. Equations have been presented to predict design dimen-

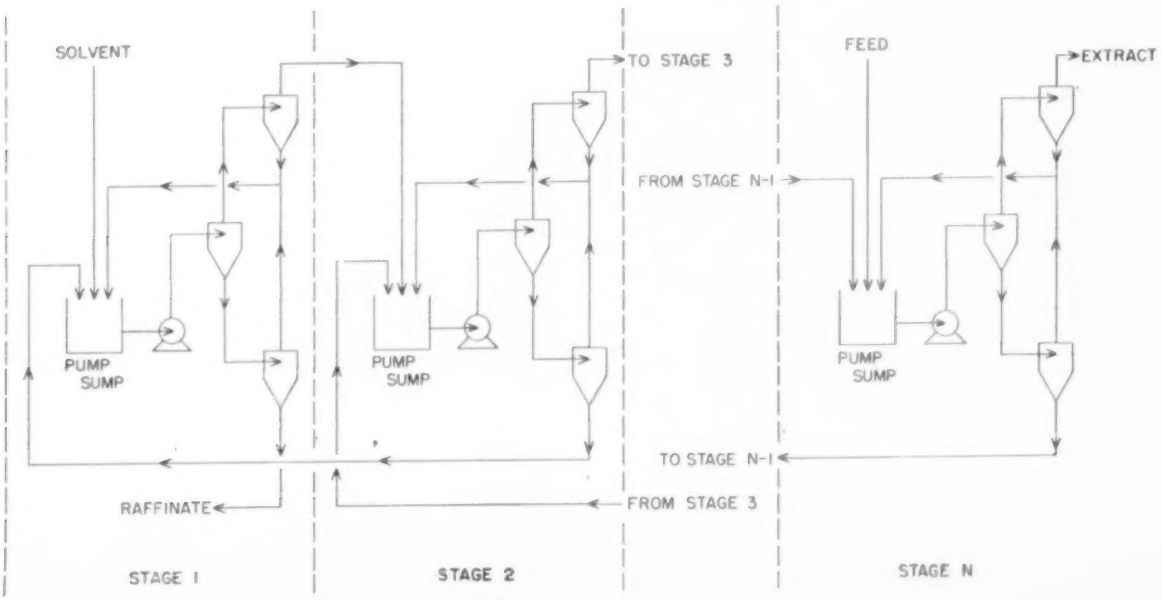

Figure 7. Proposed flow-shift. Cyclone liquid-liquid extraction.

sions, energy requirements, and classification point of any cyclone. Basic graphs are included to permit the prediction of recovery of either "float" or "sink" particles in appropriate cyclone streams. Thickening and solid elimination of particles as small as 10 microns have been achieved in other fields although 100 to 200 mesh will probably be more realistic for the food industry due to lower specific gravities. Solids as fine as 100 mesh and differing as little as a 0.02 in specific gravity have been economically separated at 95 to 100% purity and recovery in industrial cyclones. This last result has been made possible through the application of cyclone stage separation using only one feed pump for all stages. Any degree of purification and recovery is obtained by employment of the necessary number of stages.

Industrial operating examples of the above methods have been presented to exhibit the cyclone's practical potential. Many of these installations have resulted in economical continuous operation by replacing former expensive batch methods or manual labor. The actual results agree favorably with the estimated values based upon the calculation methods included in the paper. Finally, 2 cyclone modifications, the open-top cyclone and the liquid-liquid cyclone, were discussed to indicate future applications now being investigated.

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Nomenclature

- b = Feed diameter of cyclone, inches
- C = Proportionality constant = (μ) (G.p.m.)$^{0.50}$/(cb)$^{0.68}$ $\left(\frac{1.73}{\rho_s - \rho}\right)^{0.5}$
- D = Particle diameter, feet
- e = Overflow diameter of cyclone, inches
- F = Energy loss, feet of fluid
- f_D = Friction factor for relative motion of solid particles and fluid, dimensionless
- G.p.m. = Gallons per minute
- g = Acceleration due to force of gravity, ft./sec.^{2}
- K = Proportionality constant = G.p.m./$\sqrt{F}$ (eb)$^{2.0}$
- K' = Proportionality constant = $V_t r$
- K'' = Proportionality constant = $V_t r^n$
- M = Mass of fluid particle
- n = Exponent in equation $V_t = K''/r^n$
- r = Radius of curvature, feet
- V_m = Terminal settling velocity of particle, feet/sec.
- V_t = Tangential velocity, feet/sec.
- ρ = Liquid or suspension density, pounds/ft.^{3}
- ρ_s = Solid density, pounds/ft.^{3}
- μ = 50% classification point, microns
- h = Denotes heaviest specific gravity solid
- l = Denotes lightest specific gravity solid

Applications of Glassine Paper in Food Packaging

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(Manuscript received October 19, 1952)

Although glassine paper is historically one of the oldest food packaging materials, it can qualify in many respects as a recent development in flexible food packaging materials by virtue of continuing study of its manufacture and use.

The history and manufacture of glassine are briefly discussed. The basic properties of glassine are discussed together with the manner in which these properties are improved to fit specific end use requirements through various converting operations and materials.

Converted glassines are compared with other widely used present-day materials, with specific reference to laboratory evaluation. Laboratory data covering the functional characteristics of these materials are presented. Specific examples of food packaging in converted types of glassine paper are cited to illustrate some of the basic principles involved.

Glassine paper occupies an almost unique position in flexible food packaging, spanning as it does the period covered by the transition from bulk to unit packaging of a continually expanding list of food products. In recent years paper products have been supplemented by synthetic films and metal foils. However, glassine type papers have proved versatile and readily susceptible to modification for widely different end uses at lowest cost.

Prior to considering the evaluation of glassine paper for various food packaging applications, a few notes on the manufacture and the basic functional properties of glassine are in order.

GLASSINE MANUFACTURE

Glassine paper is made from high grade sulphite or kraft wood pulps and in a very general sense, its manufacture is quite similar to that of any fine paper. However, in the stock refining stage, there is an essential difference in the degree of refining which glassine stock receives. By controlled slow refining, water is combined with the pulp fibers at the same time that the usual mechanical attrition of the fibers is being carried out. While the mechanism of this water-cellulose combination is not definitely known, the effect produced in the paper is greaseproofness.

Paper so prepared is known as "greaseproof" in the paper industry. Greaseproof is a "goods-in-process" stage in glassine manufacture. As each reel of greaseproof is rewound at the end of the paper machine, it is redampened with water and passed in a separate operation through a super-calender. This equipment in effect is a calender stack of alternating steel and paper

rolls which with temperature and pressure as variables produce a continuous "ironing" of the greaseproof; the resultant dense, transparent paper is known as glassine. The smooth dense surface of this sheet provides an admirable medium for converting operations.

It should be mentioned, that supercalendering is applicable to other grades of paper. High grade bleached krafts may be supercalendered and a smooth dense surfaced sheet prepared which while not as dense or greaseproof as glassine may be converted similarly. This type of paper is used for food products not requiring the greaseproofness of glassine, but which require strength characteristics not available in glassine.

GLASSINE CONVERSION

Although the basic properties of glassine are such as to recommend it immediately for certain food items, converting operations yield an extensive variety of papers well suited for economical efficient packaging of a diversity of food products. The converting processes used with glassine are those common to other papers and films and include printing, coating and laminating.

Glassine is printed by the aniline process for the most part. Aniline printing is both practical and economical for line and coarse screen work. Where fine screen reproduction is required, rotogravure printing is employed. This is a more costly process when short runs are made, but costs fall in line with aniline when long runs are possible.

Glassine coatings are applied by 3 fundamentally different methods; "hot melt" waxing, extrusion, or solvent applications. In considering this phase of the subject, we shall deal solely with the materials used.

The most common and inexpensive hot melt material used for glassine is refined paraffin wax. To date no single thermoplastic material has been found which equals the low cost, ease of application and moisture-proofing quality of paraffin. In recent years paraffin waxes have been modified with other thermoplastic compounds such as polyisobutylene, butyl rubber and polyethylene. These additives serve the purpose of remedying some of the disadvantages of paraffin wax coatings. Paraffin films on paper are easily smeared or scuffed and paraffin waxed papers have weak heatseals when compared to the heatseal of solvent coated papers or synthetic films. Paraffin wax additives used in low concentrations can improve heatsealing, add gloss and scuff resistance, and improve the flexibility of the film without impairing the water vapor permeability or cost factors appreciably.

The second class of glassine coatings are those which are applied from organic solvent systems. These coatings, although more expensive than the wax types are more advantageous for many applications since they are characterized by excellent optical properties, mar and scuff resistance and by strong heatsealing. The principal coatings used on glassine and other papers are cellulose nitrate, cyclicized rubber (Pliolite), vinyl copolymers, and polystyrene-butadiene copolymers. Other materials such as the polyamides and ureaformaldehydes may be used for specialty grades.

In addition to the properties noted, most of the solvent coatings possess good moisture-resistance. This quality can be varied at will by changes in formulation, giving a range of moisture-resistance suitable for widely different uses.

The third and most recent development in paper coating is the extrusion method. To date polyethylene has been the chief material extruded on paper, although Saran films are also commercially produced to a limited extent. The effect of polyethylene-paper development for food packaging has not as yet been fully realized. The tough, flexible, chemically inert properties of polyethylene-paper combinations have made them an immediate and logical choice for many non-food products which include soaps, detergents, chemicals, pharmaceuticals and metal goods. Food packaging applications have not been neglected, however. Polyethylene applied to kraft papers makes a locker paper with good low temperature characteristics. Extruded polyethylene films combined with foil-glassine papers afford an extremely successful material for packaging highly hygroscopic food products. The list of uses is by no means exhausted by these items and is in the process of expansion.

Laminating two or more sheet materials to form a bonded structure is a converting process used extensively by the glassine industry. Lamination is generally accomplished with adhesives applied either in the molten state or from dispersions in water or organic solvents.

Microcrystalline paraffin wax, not many years ago a waste product of petroleum refining, has proved peculiarly adapted to glassine lamination. In fact it is today the basic adhesive used in hot melt laminating. Fundamentally it is moisture-proof, flexible and has good adhesive properties suited to bonding paper to paper, films or foils.

Laminating with adhesives in solvent media is commonly used to combine glassine or other materials to aluminum foil. The chief advantage of these materials is that they provide extremely strong bonds with a much smaller quantity of adhesive than is possible with the wax types. They do not fulfill any other functional purpose and hence are generally used with foil laminations only where the glassine or paper and foil provide the necessary protective characteristics.

By a judicious selection of the proper converting methods and materials, it is possible to create innumerable combinations of packaging materials suited for almost every flexible food package need.

GLASSINE EVALUATION

Having outlined some of the pertinent aspects of the manufacture and conversion of glassine, we are in a position to examine some of the ways in which glassine and other sheet materials are evaluated in the laboratory.

Weight (1). Weight is such an obvious and basic characteristic that its importance is sometimes overlooked. All of the physical strength characteristics vary with weight and, of equal importance to the purchaser, the yield or area per pound varies with weight.

Glassine is made in a variety of standard weights ranging from 18 to 50 pounds per ream. Ream weights are expressed on a basis of 500 24″ × 36″ sheets or in other words, 3000 sq. ft. of paper per ream *(2)*. Other paper grades which may be finished or converted as glassine generally range from 20 to 70 pounds.

Physical strength. Of equal importance with weight, physical strength characteristics make up a large segment of the functional properties of glassine. Physical strength is made up of a number of components, each of which can be measured. These include bursting strength, internal tearing strength and tensile strength.

Physical strength varies with weight. However, weight is not the only operative variable. Other variables which influence strength include pulp furnish, fiber length, degree of greaseproofness and the type and quantity of humectants which may be incorporated with the paper to maintain a proper level of moisture content.

Figure 1 shows the variation of bursting and tearing strengths with weight which is characteristic of a bleached glassine having a furnish of 70% sulfite-30% kraft, a moisture content of 6% and a plasticizer or humectant content of 7%. Greaseproofness for all weights is 300 seconds.

Bursting strength *(3)* is defined as the hydrostatic pressure required to produce rupture of a circular area of the paper 1.20 inches in diameter when pressure is applied at a controlled increasing rate. The specimen is rigidly clamped about the perimeter of the test area but is free to bulge under the pressure applied. Bursting strength or points Mullen can be measured up to a value of 200, each point of Mullen being approximately equal to 1 p.s.i.

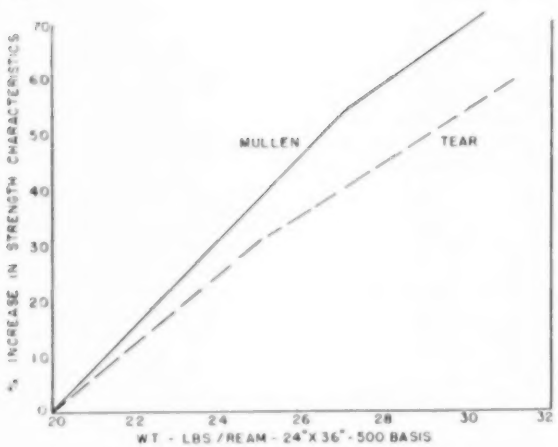

Figure 1. Physical strength vs. weight

Internal tearing resistance *(4)* is defined as the average force in grams required to tear a single sheet of paper after the tear has been started. The Elmendorf tear-testing instrument which is standard in the paper industry measures the work done in tearing a given number of sheets of paper and expresses this work as g. per cm.

Tensile strength *(5)* may be defined as the force in pounds per inch width of paper which is required to break the paper under tension applied at a gradually increasing rate. Results may also be expressed in kilograms per 15 mm. width. This characteristic is closely allied with bursting strength.

Greaseproofness (6). Alluded to in the preceding sections in general terms, at this point we may define greaseproofness from the laboratory standpoint as the number of seconds required for a standard C.P. turpentine to penetrate a specimen of paper. This interpretation of greaseproofness is of course an arbitrary one, but it serves as a quick, fairly reliable mill control determination.

Most glassines are manufactured against greaseproof specifications which may range from a nominal 20-second penetration time to a maximum of 1800 seconds. The following greaseproof relationships are of interest both to the mill and also to the purchaser. First, as greaseproofness is increased, production is decreased and unit costs mount. Secondly, physical strength is affected by changes in greaseproofness, other conditions remaining constant. Tearing strength varies indirectly with greaseproofness and bursting strength varies directly as shown in Figure 2. For this example, 25 lb. blea. glassines with 6% moisture and with no plasticizer were selected.

Further, increases in greaseproofness are accompanied by an increase in apparent hardness or stiffness of the sheet. This condition is met by the addition of humectants which tends to increase tearing resistance and to lower bursting strength.

It can be appreciated that the number of possible types of glassine is considerable. Close cooperation between the glassine manufacturer and the consumer will benefit both by enabling a selection of a sheet with optimum properties for a particular use.

Transparency. Transparency may be expressed mathematically as a percentage value of the ratio of parallel light transmission to total light transmission, with both types of transmission being measured photoelectrically. Parallel transmission is the ratio of the amount of light leaving a sheet of paper in a small range of angle from the perpendicular to the total amount of light falling upon the sheet. Total transmission is a ratio of the amount of light passing through the sheet to the total amount of light falling upon the sheet.

While transparency is capable of exact definition and measurement, it remains a concept which is loosely interpreted. Although there are undoubtedly times when the ultimate in transparency is desired, most food packaging applications are satisfied by the level of transparency afforded by glassine when, for example, the product is in close contact with the wrapper. There are a considerable number of large volume food items which do not need any transparency factor in their packaging. To fill this need glassine is made in white or colored opaque grades which supply attractive printing backgrounds and protection against light.

Heatseal and blocking resistance. These are closely related characteristics of coated glassines since both are influenced by the same variables: time, pressure, temperature and humidity. In general, as heatsealing strength is increased, blocking resistance decreases.

Blocking resistance is simply measured by subjecting a sheaf of test papers to fixed conditions. A convenient set of conditions for solvent coated papers is 1/3 p.s.i. at 120° F. for 4 hours. When paraffin wax coatings are tested, it is necessary to drop the temperature to 100° F. In either case, the critical point of observation is

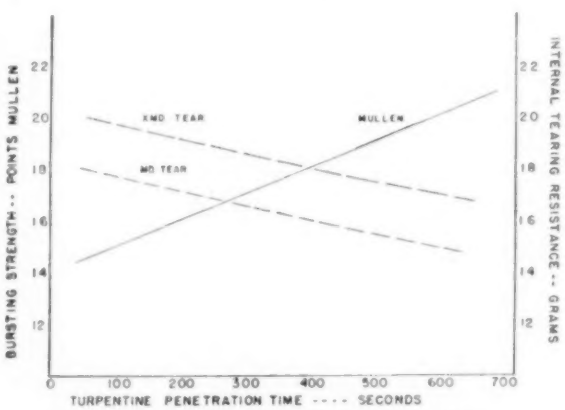

Figure 2. Physical strength vs. greaseproofness

whether the specimen blocks. Symptoms of blocking include loss of surface gloss, actual marring of the film or even a sealed state. If coated test papers do not block under these conditions, they will not block in roll or sheet form under normal conditions of storage or transportation.

The evaluation of heatseals is dependent upon the type of coating. Wax heatseals can be measured readily by several different methods since the actual force in grams or pounds required to separate sealed specimens can be accurately measured. A standard method of

heatseal evaluation for waxed papers is now in process of preparation by a joint committee of TAPPI and ASTM. Optimum sealing temperatures for waxes range from 180°–220° F. For laboratory evaluation a sliding contact is used to produce the seal rather than a reciprocating or rotary contact.

Heatseals of solvent coated papers present a different evaluation problem in that separation of these seals is generally accompanied by a defibering or tearing of the glassine or paper base. Instrument measurements of these seals would therefore give not only the strength of the seal but that contributed by the paper fibers. Evaluation of these seals consequently remains on a manual and empirical basis. Figure 3 shows typical heatseal strength vs. sealing temperature curves which may be derived from this method of testing various types of solvent coatings on glassine. The samples chosen for this example were coated with 3 pounds of coating per ream. Reciprocating type heatseals were made on a Wrap-Ade heatsealer with a dwell time of 0.5 second at constant pressure.

Water vapor permeability. Of all of the properties of packaging materials, water vapor permeability has had the greatest attention from research and technical sales personnel. The glassine industry has standardized on the permeability measurement method of Southwick and Rhodes, known as the General Foods method. Semi-annually all glassine mills cooperate in conducting a round robin test for the purpose of correlating WVP data. Results in general are in good agreement.

Just as the physical strength characteristics of paper are dependent upon a large number of variables, so the WVP may be influenced by the same or different variables. Table 1 shows the relative ranges of water vapor transmission which appear to be characteristic of various packaging materials. Water vapor transmission rates given are expressed as g. per 100 sq. in. per 24 hours at 100° F. with a relative humidity differential of approximately 95%.

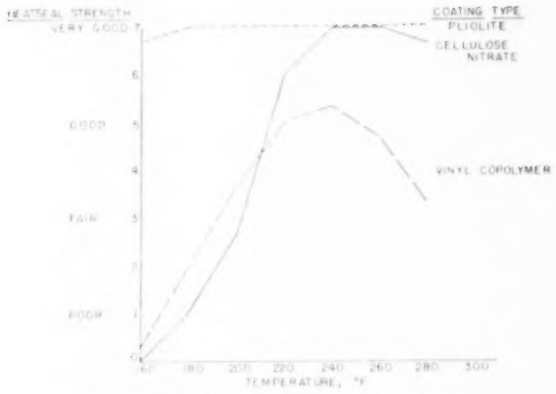

Figure 3. Heatseal temperature ranges

The question is raised many times, when permeability data of this type is presented, as to whether the rates which are determined over a 3-day period may not be indicative of WVTR when determined over a longer period of time. Figure 4 contains typical long term permeability curves of a waxed glassine, a laminated glassine and a coated foil-glassine lamination.

Water vapor permeability measurements of this type should be regarded as an academic approach to the problem of moisture protection evaluation in food packaging. These data must be supplemented by an evaluation of the product to be packaged with reference to its moisture protection requirements as determined by equilibrium moisture content studies. Further, permeability of the final package is of greater importance than the permeability of the sheet material alone.

Package storage tests furnish a convenient means by which the finished package may be evaluated for product

TABLE 1

Water vapor transmission rates

Package material					G. F. WVTR	
					Grams/100 sq. in./24 hrs.	
Type	Paper	Ream wt.	Coating or Laminant	Ream wt.	Flat	Creased
Waxed	Glassine	20-25	100% Paraffin	3-4	0.20-0.40	3.0-5.0
Waxed	Glassine	25	100% Paraffin	5-7	0.10-0.20	2.5-3.5
Waxed	Glassine	25	Modified paraffin	5	0.20-0.40	3.0-5.0
"Dry" Waxed	S. C. Sulfite or Kraft	25	100% Paraffin	5	15.00-30.0	high
"Wet" Waxed	S. C. Sulfite or Kraft	25	100% Paraffin	10	0.70-2.00	9.0-12.0
Coated	Glassine	22-25	Nitrocellulose	3	0.40-0.60	4.0-6.0
Coated	Glassine	22-25	Cyclized rubber	3	0.15-0.25	0.4-0.8
Coated	Glassine	22-25	Butodiene-polystyrene	3	0.15-0.25	0.3-0.6
Coated	S. C. Sulfite or Kraft	25-32	Nitrocellulose	5-8	0.70-1.40	5.0-8.0
Coated	Glassine	22-25	Vinyl copolymer	3	2.50-4.00	5.0-8.0
Extruded	Glassine - S.C. Sulfite or Kraft	25-50	Polyethylene	7-5	2.50-3.50	2.5-3.5
Extruded	Glassine - S.C. Sulfite or Kraft	25-50	Polyethylene	15.0	1.30-1.80	1.3-1.8
Extruded	Glassine - S.C. Sulfite or Kraft	25-50	Polyethylene	30.0	0.60-1.00	0.6-1.0
Laminated	Glassine	2 × 25	Microcrystalline	7	0.30-0.60	0.30-0.60
Laminated	Glassine	2 × 25	Microcrystalline	10	0.20-0.50	0.20-0.50
Laminated	Glassine - S.C. Sulfite or Kraft	2 × 25	Microcrystalline	5	1.00-2.00	2.00-4.00
Laminated	Glassine - S.C. Sulfite or Kraft	2 × 25	Microcrystalline	15	0.30-0.50	0.50-1.00
Laminated and Coated	Glassine	2 × 25	Microcrystalline wax Nitrocellulose	7 3	0.15-0.25	0.20-0.40
Laminated and Coated	Glassine	2 × 25	Microcrystalline wax Cyclized rubber	7 3	0.10-0.15	0.20-0.40
Laminated	Glassine foil	25 + 15	Microcrystalline wax	7	0.01-0.02	0.15-0.30
Laminated	Glassine foil	25 + 15	Resin or latex	3	0.01-0.02	0.40-1.00
300 MST Cellophane 54					0.40-0.60	
140 N_2 Pliofilm					0.60-0.70	
100 gauge Saran 517					0.16-0.20	

protection. Tests of this nature are carried out by both the food manufacturer and the package material producer. In many cases, both conduct duplicate concurrent tests.

The technique of package storage testing is quite simple in concept, but may at times become involved in practice. In any case, no matter what the problem, packages of the particular product are formed either manually or on automatic equipment, filled, sealed and stored under appropriate temperature and humidity conditions. Although certain special applications, frozen

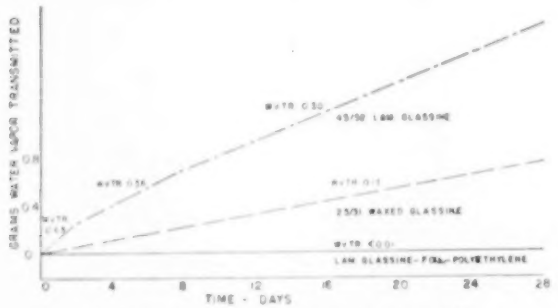

Figure 4. Long-term water vapor permeability

food materials for example, require special conditions, the commonest conditions range from 80° to 100° F. and from 80% to 90% R. H. The moisture gain of the product is ascertained indirectly by weighing the packages under the storage conditions or directly by A.O.A.C. or by other standard methods of moisture content determination on the product. The direct method is preferred by far, but there are times when the indirect method proves more practical. Concurrently with the determination of moisture gain, the product will be examined for changes in taste, odor or appearance while the package itself will be checked for grease spotting, mold growth, glue line separation, or, in short, for any undesirable sign of deterioration of the product or package.

The scope and practicability of this technique can perhaps be illustrated with several studies of different products and package types.

The first relates to cracker packaging. This study came about as a result of a large biscuit manufacturer's development of a new type of package—which made necessary a modification of package materials. The standard one-pound carton with printed overwrap and waxed glassine liner was to be compared for moisture protection against the new package which contained individually wrapped and sealed one-quarter pound units. In addition, the performance of cellophane for this application was to be checked. Two other factors involved in the change-over had already been decided upon. The new liner needed improved heatsealing properties and greater strength. These considerations were satisfactorily met by using a modified paraffin wax coating and by an increase in weight of the base paper. For this test, then, sheet materials were prepared and checked in the laboratory for weight of wax film and for water vapor transmission values. These data are presented in Table 2. Packages were prepared by hand

TABLE 2

Cracker test data

Material	Basis weights, lbs./ream			WVTR Grams/100 sq. in./24 hrs.	
	Paper	Wax	Total	Flat	Creased
29/37 Waxed Blea. Glassine 100% 138/40 paraffin	28.0	7.8	35.8	0.06	1.47
29/37 Waxed Blea. Glassine 95% 138/40 paraffin 5% Butyl Rubber	29.5	8.3	37.8	0.05	1.87
25/29 Waxed Amber Glassine 100% 138/40 paraffin	25.4	4.5	29.9	0.21	2.20
300 Moisture Proof, Heatsealing Cellophane	—	—	—	0.60	2.45

using bakery fresh product and stored at 90°-95° F. and 80%-85% R. H. Results of moisture content determinations are given in Figure 5.

It will be seen that both the sheet material tests and the storage tests indicate that the product is better packaged in the new type unit, with waxed glassine as the logical material to be selected.

A second example of a package test may be offered to indicate the possibilities of waxed glassine as a protective outer wrap. Figure 6 contains moisture content data obtained from a cereal product packaged in the standard printed carton, lined with waxed glassine. This pack has adequate protection characteristics for northern climates. However, for distribution in the South during the summer season, an additional factor of

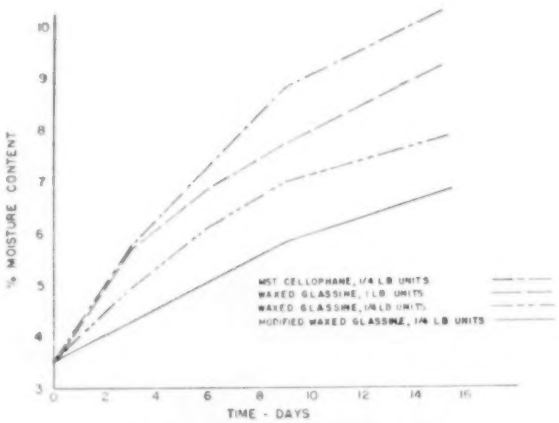

Figure 5. Cracker carton overwrap study

moisture protection was necessary. For this study, the regular carton was overwrapped with 300 moisture-proof, heatsealing Cellophane and compared with similar cartons overwrapped with waxed glassine, similar to that used as the liner. As the moisture content curves show, the waxed glassine again proved to have definite advantages in this application.

As a third example of a food package development, data on the packaging of dehydrated non-fat skim milk powder may be given. This food product has become a large volume item with a rapidly increasing retail

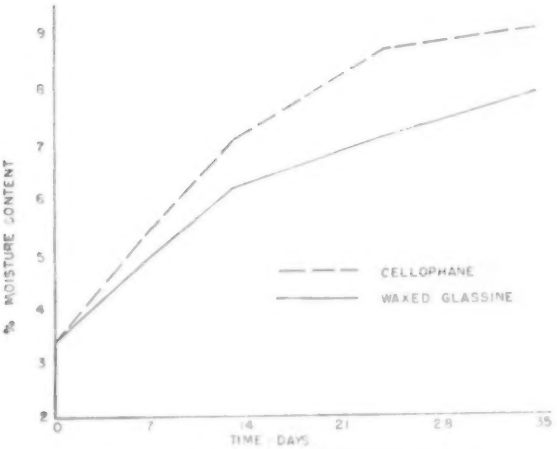

Figure 6. Cereal carton overwrap study

consumer acceptance. It is a product which requires a fairly high level of moisture protection to guard against product caking and off odor and taste development. In this study the sheet materials were used as heatsealing one-pound carton liners and all were laminated combinations. The actual composition of the materials tested is given in Table 3.

Handformed packages were prepared, filled, sealed and stored under high temperature—humidity conditions. The storage time-product moisture content relationship found under these conditions is shown in Figure 7. The super-calendered bleached kraft-foil-polyethylene combination was found to be significantly superior in moisture protection. This study was conducted at a time when foil and polyethylene were both in short supply. Since this situation has eased, a material very similar to the combination tested is being used commercially.

TABLE 3

Dehydrated skim milk powder package test
24x36-500 basis weights

Material	Paper	Foil	Film	Laminant or coating	Total wt.
A. Greaseproof Wax laminated to Cellophane	29.1		22.4	10.8	62.3
B. S. C. Kraft Wax laminated to Glassine, coated 1 side	13.5			14.5 L	
	25.1			37.0	73.8
C. S. C. Kraft Glue lam. to alum foil with polyethylene extruded coating	26.3	15.4	10.6	1.3 L	53.6

The merits of the paper-foil-polyethylene lamination include the possibility of its use alone on automatic equipment. Another application which is ready for commercial development is exemplified in the packaging of a nationally known dehydrated soup mix. For this application, the outer super- calendered kraft side is multicolor printed and overcoated with a high gloss lacquer which adds moisture, grease and scuff resistance to the package. The combination also has attractive cost and yield factors in addition to its valuable functional properties.

In concluding it may be well to emphasize that the few laboratory studies cited represent only a very small fraction of recent food packaging applications of glassine and converted glassine type papers. They do not represent, of course, the very great number of standard uses which play an essential and familiar part in flexible food packaging.

To those interested references *7* to *21*, inclusive, will provide a detailed discussion of these uses.

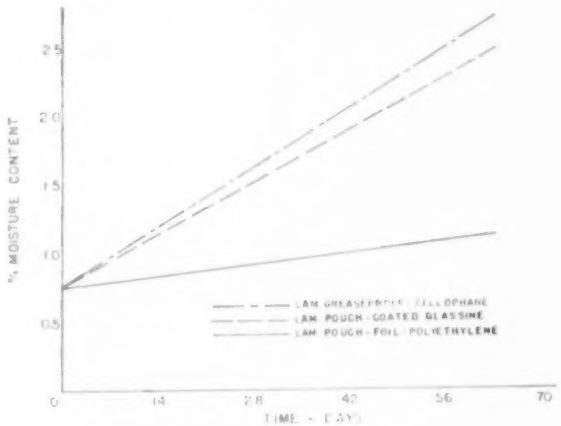

Figure 7. Dried skim milk carton liner study

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Flavor of Peanuts and Peanut Products as Affected by Certain Insecticides Used in Growing Peanut Crops

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(Manuscript received August 27, 1952)

Evidence is presented to show that the use of certain insecticides in growing peanuts may cause off-flavors in peanuts and peanut products, including unroasted, oven-roasted unsalted and salted whole peanuts, peanut butter, and peanut oil. Insecticides studied were technical benzene hexachloride, lindane, aldrin, dieldrin, and toxaphene. Dosage and method of application varied with the insecticide.

Serious damage to or loss of crops caused by insect infestation has made the use of insecticides an economic necessity in growing peanuts. Benzene hexachloride (BHC) and lindane (the purified gamma isomer of BHC) are effective in the control of certain insects but impart off-flavors or off-odors to some food crops. Palatability studies on roasted peanuts, peanut oil, and peanut butter carried out in several laboratories and reported by Poos, Dobbins, Batten, and Boush *(10)* also show that these insecticides may adversely affect the flavor of peanuts. The report suggests that roasting may accentuate off-flavors and off-odors.

Although data are lacking on the effect of dosage rate and method and time of applying the insecticide in growing peanuts, studies with other foods *(3, 5, 7, 8, 12)* have indicated that these are pertinent factors in the effect of insecticide treatments on the flavor of foods.

Although there have been some studies of the effect on flavor of food crops from use of such other insecticides as aldrin, dieldrin, and toxaphene, none have been reported for peanuts. Griffiths, Reitz, and Olsen *(6)* detected no off-flavors in the juice of Florida oranges from trees sprayed with toxaphene; and Smith, Jones, and Rigney *(11)* reported that spraying peach trees with toxaphene did not affect the flavor of the fruit. On the other hand, Gould and associates *(1)* found that toxaphene imparted an off-flavor to some fruits and vegetables, which was noticeable in the canned products; and Allen, Bondy, Bullock, and Hall *(2)* reported that foliage applications of toxaphene gave an undesirable taste to tobacco.

The present studies to evaluate the flavor of peanuts produced with different insecticide treatments were carried out over a period of 3 years on samples provided by the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. Peanuts were tasted as whole peanuts or after processing into peanut butter. One series of tests was made on oils pressed from treated and untreated peanuts. Insecticides used in growing the various samples were technical benzene hexachloride, lindane, aldrin, dieldrin, and toxaphene. Dosage rate and method of application varied with the insecticide.

MATERIALS AND METHODS

Palatability tests were first made in 1949 on whole Virginia Runner peanuts grown at the Virginia Agricultural Experiment Station in untreated soil and in soil to which insecticides were applied with the fertilizer according to regular field practice. The insecticides used in growing the peanuts were 1 pound lindane per acre, and technical benzene hexachloride at a dosage rate to give 1 pound gamma isomer per acre.

Each lot of peanuts was prepared in 3 ways: Unroasted, oven-roasted, and oven-roasted and salted. Three replications were made. Unroasted samples were tasted raw after skins were removed. For roasting peanuts ovens were preheated to 375° F. (190.5° C.). Samples from untreated soil were roasted for 20 minutes, whereas those grown in treated soil required only 18 minutes to become equally brown. Skins were removed from roasted nuts after the nuts had cooled slightly. For salted peanuts, nuts prepared as roasted nuts were heated for 3 minutes in a small amount of hydrogenated vegetable fat in a fry pan, with constant stirring to insure even heating. Peanuts were spread on absorbent paper to remove excess fat, then 1 teaspoon salt per cup of nuts was added.

Both roasted and unroasted samples were stored at 75° F. (24° C.) for a few days while the judging sessions were being held. Three samples, prepared the same way, one from each of the different lots grown with or without insecticides, were judged at each session. Samples were served in random order in coded glass custard cups to 6 experienced judges who rated the nuts on absence of off-flavor and general acceptability, using 5-point scales for each factor.

To provide for more uniform samples than is possible with whole peanuts, subsequent palatability studies were made on peanut butter samples prepared in the pilot plant of the Bureau of Plant Industry, Soils, and Agricultural Engineering from the experimental lots of peanuts to be tested.

Samples tested in 1950 were of the Virginia Jumbo variety. In one series, comparative studies were made of samples grown on farms in southeast Virginia in soil to which 1 pound of lindane or 4 pounds of aldrin per acre were applied with the fertilizer, following regular field practice. This experiment was replicated in 3 locations, and samples of peanut butter were made from each of the 3 replications.

Another group of samples was grown at the Virginia Agricultural Experiment Station in small plots to which insecticides were applied to the soil by hand at the rate of ¾ pound lindane, 2 pounds of dieldrin, or 25 pounds toxaphene per acre; each treatment was replicated 5 times. Peanuts from the 5 replicates of each treatment were pooled to make one peanut butter.

Peanuts from small plots at the Virginia Agricultural Experiment Station where insecticides were applied with hand equipment to the foliage were also studied. Treatments used in these tests were 4 applications of 2% aldrin dust, 2% dieldrin dust, or 10% toxaphene dust. Each treatment was replicated on four plots and the samples from each treatment were pooled to make a composite for processing into peanut butter.

Untreated checks were provided for all groups of samples studied and a special lot of peanut butter from nuts grown in an untreated field was prepared for use as a known reference and coded control sample.

Peanuts for the peanut butter were kept at 70° F. (21° C.) or lower for a short time before they were shelled and processed. The peanut butter was stored at 40° F. (4.4° C.) until shortly

before judging when it was brought to room temperature. One-half teaspoon samples of peanut butter were served on coded small white china plates. Five judges who had been trained on known commercial and experimental samples rated 3 replicate samples from each lot of peanut butter on 5-point scales for absence of off-flavor and general acceptability. Samples were presented in random order at 3-minute intervals, and no more than four samples were judged at any session.

In another study, the quality of peanut oil made from Virginia Jumbo peanuts grown in 1950 in southeast Virginia in soil with and without treatment with various insecticides was evaluated by rating the flavor of french-fried potatoes cooked in the peanut oils. This method of evaluation was selected because french frying is a common use for peanut oil, and the bland flavor of potatoes is not likely to mask off-flavors that may result from the insecticide treatment. The peanut oils tested were made from peanuts grown with the following insecticides used as soil treatments applied with the fertilizer: Technical benzene hexachloride at a dosage rate to give 1 pound gamma isomer per acre, 1 pound lindane per acre, or 4 pounds of aldrin per acre. Oil from peanuts grown in soil having no history of previous benzene hexachloride treatment and a commercial peanut oil were used as check samples. Cold-pressed samples of peanut oil were prepared by the Planters Nut and Chocolate Company, Suffolk, Virginia.

For french-frying, California potatoes of an unidentified variety were chosen. By cooking tests these were found to be the most suitable of the potatoes available at the time of the studies. The potatoes were washed, peeled, and cut into $\frac{3}{8}$-inch strips with a french-fry cutter. The picric acid test for reducing sugars employed by Peacock and Brunstetter *(9)* was used on the center strip of each potato, and potatoes having moderately low and comparable sugar content were selected for use. The 2-step method for french frying potatoes as standardized by Alexander, Schopmeyer, and Anderson *(1)* was used, with modifications for variety of potatoes and smaller quantities of oil. The amount of peanut oil used was 3 times the total weight of the potatoes. The same oil was used 3 times in succession, adjusting the weight of the potatoes for each frying to the weight of the oil, keeping the proportion of 3 to 1.

Palatability of the hot, unsalted french-fried potatoes was rated immediately by an experienced panel of 5 persons who scored the samples on 5-point scales for absence of off-flavor and general acceptability. Three samples, at least one of which was an untreated sample, were served in random order at 5-minute intervals on individual coded white china plates. Each sample consisted of 5 potato strips selected at random from the lot cooked in one of the oils.

Palatability scores from all studies were analyzed statistically to aid in interpretation of results.

RESULTS AND DISCUSSION

Peanuts. Samples from fields treated with technical benzene hexachloride or with lindane were scored lower on both absence of off-flavor and general acceptability than parallel samples from untreated fields (Table 1). When scores for both of the above quality factors were analyzed statistically, differences in the scores for samples from treated and untreated fields were significant for roasted peanuts, either salted or unsalted, but were nonsignificant for unroasted nuts. It is possible that roasting emphasized the off-flavors in the peanuts or that any off-flavors attributable to insecticide treatment were masked by the characteristic flavor of the raw, green peanuts.

Although the scores for absence of off-flavor and general acceptability for peanuts from lindane-treated soil tended to be slightly higher than those for peanuts from technical benzene hexachloride-treated fields, the differences were not large enough to be statistically significant. Judges' ratings indicated that moderately strong off-flavors were noted in roasted samples where technical benzene hexachloride had been used and slightly less pronounced off-flavors were noted where lindane was employed as the insecticide. Moderately strong off-flavors were observed when samples from fields treated with either insecticide were prepared by roasting and salting.

TABLE 1

Mean palatability scores for unroasted, oven-roasted, and oven-roasted-salted peanuts grown in untreated soil, in soil treated with technical benzene hexachloride, and in soil treated with lindane

Preparation method	Soil treatment	Mean palatability score[a]	
		Absence of off flavor	General acceptability
Unroasted	Untreated check	3.2	3.2
	Technical benzene hexachloride[b]	2.7	2.8
	Lindane[c]	2.8	2.7
Oven roasted	Untreated check	3.7	3.5
	Technical benzene hexachloride	2.2	2.3
	Lindane	3.0	2.9
Oven roasted and salted	Untreated check	3.8	3.5
	Technical benzene hexachloride	2.3	2.4
	Lindane	2.6	2.6

[a] Average of 3 replicates rated by 6 judges. For absence of off flavor a score of 5 represents no off flavor; 4, perceptible off flavor; 3, slightly strong off flavor; 2, moderately strong off flavor; 1, very strong off flavor. For general acceptability, a score of 5 indicates a very good product; 4, good; 3, fair; 2, poor; and 1, very poor.

[b] Dosage rate to give one pound of gamma isomer per acre.

[c] Dosage rate, one pound per acre.

Scores for general acceptability indicated that the judges considered the peanuts grown using benzene hexachloride or lindane only *fair* to *poor* in over-all eating quality. Peanuts from untreated soil were judged to be *fair* to *good* in quality. The mediocre quality of peanuts from untreated fields may have been a consequence of insect injury. Differences in amount of injury between treated and untreated plots were highly significant according to Poos, *et al. (10)*.

Peanut butter. One pound of lindane per acre mixed with the fertilizer used in growing peanuts was detrimental to flavor and general acceptability of peanut butter made from the peanuts. Average scores were significantly lower than those of peanut butter from peanuts grown in untreated soil (Table 2). Musty off-flavors made this sample so unpleasant that the judges found it barely edible; in general acceptability it rated *poor* to *very poor*. On the other hand, when aldrin was applied at the rate of 4 pounds to the acre, flavor and general acceptability scores of the peanut butter were comparable to those for the control sample. Judges did note, however, that the product from aldrin-treated soil was sweet and somewhat chalky, but they did not consider these characteristics as serious defects.

When insecticides were applied to small plots by hand, peanuts from lindane-treated soil again were found to carry musty off-flavors which were noticeable in the peanut butter. The mean score indicated that slightly strong off-flavors were observed when lindane was applied at the rate of $\frac{1}{4}$-pound per acre. Some judges considered the product *edible* but disappointing, while others rated it *inedible*. In general acceptability, it rated *fair* to *poor*. Both flavor and acceptability scores were significantly lower for the sample from lindane-

TABLE 2

Mean palatability scores for peanut butter made from peanuts grown without use of insecticides or using various insecticides applied by different methods

Insecticide and method of application	Mean palatability score[a]	
	Absence of off-flavor	General acceptability
Insecticide applied to soil in fertilizer[c]		
Untreated check	3.8	3.4
1 lb. lindane/acre	2.2	1.7
4 lb. aldrin/acre	3.6	3.2
Insecticide applied to soil by hand[f]		
Untreated check	3.8	3.1
2 lb. dieldrin/acre	4.5	3.9
25 lb. toxaphene/acre	4.0	3.5
¼ lb. lindane/acre	3.1	2.5
Insecticide applied to foliage[f]		
Untreated check	4.0	3.4
2 percent aldrin dust	4.1	3.5
2 percent dieldrin dust	4.3	3.9
10 percent toxaphene dust	3.1	2.5

[a] Mean of 3 replicates scored by 5 judges on a 5 point scale. For absence of off-flavor, a score of 5 represents no off-flavor; 4, perceptible off-flavor; 3, slightly strong off-flavor; 2, moderately strong off-flavor; 1, very strong off-flavor. For general acceptability, a score of 5 indicates a very good product; 4, good; 3, fair; 2, poor; and 1, very poor.

[c] Regular field practice.

[f] Small plots.

treated plots than for the samples from untreated plots or from those in which dieldrin or toxaphene had been used.

Peanut butter from peanuts grown in soil treated with 2 pounds dieldrin or with 25 pounds toxaphene per acre was, in eating quality, as good as or better than peanut butter from peanuts grown in untreated soil. In general acceptability the peanut butter from the sample grown using dieldrin was scored significantly higher than either that from the untreated check or the sample grown using toxaphene. Although the mean score on absence of off-flavor of peanut butter from the sample grown in dieldrin-treated soil was slightly higher than that of the sample from soil treated with toxaphene, the difference was not significant. Some chalkiness was noted in the samples from peanuts grown in both dieldrin- and toxaphene-treated soil and in a few instances a medicinal flavor was noted in the latter. These off-flavors, whenever observed by the panel members, were reported as barely perceptible.

When 2% aldrin or dieldrin dust was used on the foliage in growing peanuts the flavor and general acceptability scores of peanut butter made from the nuts indicated that these insecticide treatments had little if any effect on eating quality. Both of these samples had higher average scores than the untreated check, but differences in scores were not statistically significant. Slightly strong off-flavors were found in the peanut butter when 10% toxaphene dust was used on the foliage in growing the peanuts; the judges rated this sample only *fair* to *poor* in flavor and in general acceptability. Scores for the sample from toxaphene-dusted plants were significantly lower for both palatability factors than those for the untreated check or for the samples of aldrin- or dieldrin-dusted plants.

It is possible that the off-flavors in this sample may have been the result of improper curing caused by rainy weather. In later tests (unpublished) carried out in 1951, no significant off-flavors were observed in one sample of peanut butter made from peanuts grown on plants dusted with toxaphene. Definite conclusions cannot be derived from data on these samples. It is necessary, however, in view of the relatively low palatability scores given the one toxaphene-treated sample and the previously cited reports of off-flavors following toxaphene treatment of some other crops, to consider the possibility that toxaphene may, under some conditions, also impart undesirable flavor to peanuts.

Peanut oil. The oil from peanuts grown without use of insecticides and the commercial sample of oil both imparted a slight off-flavor to the potatoes on the first frying, less off-flavor on the second frying, and no off-flavor on the third. The mean scores ranged from 3.9 to 5.0 for 3 batches of potatoes fried consecutively in the sample of oil from peanuts grown in untreated soil and from 4.2 to 4.8, for those fried in the commercial sample of oil (Table 3). This may indicate that constituents

TABLE 3

Mean palatability scores for California potatoes french-fried in peanut oil made from peanuts grown in untreated soil and in soil treated with lindane, technical benzene hexachloride, or aldrin

Soil treatment	Condition of oil	Mean palatability score[a]	
		Absence of off-flavor	General acceptability
Commercial check	First use	4.2	3.6
	Second use	4.7	3.9
	Third use	4.8	3.4
Untreated check	First use	3.9	3.1
	Second use	4.1	3.2
	Third use	5.0	3.6
Technical benzene hexachloride (1 lb. gamma isomer per acre)	First use	4.4	2.9
	Second use	3.6	2.9
	Third use	3.3	2.4
Lindane (1 lb. per acre)	First use	4.8	3.5
	Second use	4.7	3.9
	Third use	4.0	3.0
Aldrin (4 lbs. per acre)	First use	4.5	3.9
	Second use	4.4	3.2
	Third use	4.0	3.0

[a] Mean of 5 scores. For absence of off-flavor, a score of 5 represents no off-flavor; 4, slight off-flavor; 3, moderate off-flavor; 2, strong off-flavor; 1, very objectionable off-flavor. For general acceptability, a score of 5 indicates a very good product; 4, good; 3, fair; 2, poor; and 1, very poor.

originally present in the oils and responsible for off-flavors were absorbed by the potatoes or volatilized during the first frying.

On the other hand, second and third batches of potatoes fried in oil from peanuts grown using any of the insecticides had more off-flavor than those fried in the fresh oil. The mean flavor scores, when oil from peanuts grown using technical benzene hexachloride was used, ranged from 4.4 for the first frying to 3.3 for the third frying, from 4.8 to 4.0 when lindane was used, and from 4.5 to 4.0 when aldrin was the insecticide used. The third batches of potatoes fried in the oils from peanuts grown in the treated soil had lower flavor scores than comparable samples fried in untreated oil. This may indicate that oils from peanuts from treated soil were decomposing upon prolonged heating at a faster rate than oil from peanuts grown in untreated soil, or that the decomposition products of oils from peanuts grown using the insecticides were stronger in flavor than those of untreated check samples.

The suggested differences in heat stability of the oils tested is supported by the observation that oil from peanuts grown in untreated soil and the commercial sample did not smoke as much during the 3 successive frying as the oils from the peanuts grown in treated soil. A very musty odor was also observed during heating of the oil and frying of the potatoes when the oil used was that prepared from peanuts grown using technical benzene hexachloride. This odor was still noticeable to the laboratory workers when the fried potatoes were distributed on plates for serving. Oil from peanuts grown in soil treated with aldrin smoked and emitted a slightly strong odor when heated to a temperature of 180° C. (356° F.).

Potatoes fried in oil from peanuts grown using lindane or aldrin had less off-flavor than comparable batches fried in oil from peanuts grown using technical benzene hexachloride. The latter had a musty aftertaste.

Mean acceptability scores for the first and the second batches of potatoes fried in oil from peanuts grown with the use of lindane or aldrin were comparable to those fried in the check samples. Acceptability scores for the third batch of potatoes fried in the oils from lindane- or aldrin-treated plots and for all 3 batches of potatoes fried in oil from peanuts grown with the use of technical benzene hexachloride were 3.0 or below, indicating fair to poor products. These acceptability scores include quality of the french fries with respect to color, moistness, tenderness, and crispness in addition to flavor. Mean scores for acceptability of potatoes fried in oil from peanuts grown in untreated soil and in the commercial oil ranged from 3.1 to 3.9, indicating a fair to fairly good product.

SUMMARY

Musty off-flavors were found in unroasted, roasted, and roasted and salted peanuts grown in soil in which technical benzene hexachloride at a dosage rate to give 1 pound gamma isomer per acre or on which lindane, 1 pound per acre, applied with the fertilizer were used as insecticides. Slightly stronger off-flavors were noted in samples where benzene hexachloride was used than in those with lindane; however, in both cases the eating quality of the peanuts was seriously impaired.

Peanut butter made from peanuts grown in soil to which lindane was applied at the rate of ¾ or 1 pound per acre had more off-flavor and was scored lower on general acceptability than peanut butter made from untreated check samples. When peanuts were grown using 4 pounds aldrin, 2 pounds dieldrin, or 25 pounds toxaphene per acre as soil treatments or 2 percent aldrin or dieldrin dust on the foliage of peanut plants, palatability of peanut butter was comparable with that made from peanuts grown without insecticide treatment. Flavor tests on peanut butter from peanuts grown with toxaphene dusted on the plants were inconclusive.

Potatoes french fried in oil made from peanuts grown in soil treated with technical benzene hexachloride (1 pound gamma isomer per acre) had slightly more off-flavor than potatoes fried in oil from peanuts grown in untreated plots or in oil from peanuts grown using 1 pound lindane or 4 pounds aldrin per acre. Second and third batches of potatoes fried in oils from peanuts from any of the insecticide-treated soils had increasingly more off-flavor than the corresponding first batch. Only the third batch of potatoes fried in oil from peanuts grown with lindane or aldrin had slightly more off-flavor than comparable potatoes fried in oil made from peanuts grown in untreated soil. The observed off-flavors were reflected in low scores for general acceptability.

Acknowledgments

The authors wish to acknowledge the assistance of F. W. Poos, Bureau of Entomology and Plant Quarantine, in selecting and providing the samples for these studies, J. H. Beattie, Bureau of Plant Industry, Soils and Agricultural Engineering, for preparing the peanut butter, Nancy A. Smalley and Patricia Trimble, formerly of the Bureau of Human Nutrition and Home Economics, for assistance in the laboratory, and Elsie F. Dochterman and Albert B. Parks, Bureau of Human Nutrition and Home Economics, for statistical analysis of the data.

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Value of Nitrogen for Stabilizing Reduced Ascorbic Acid in Milk[a]

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(Manuscript received September 11, 1952)

A method for treating milk with nitrogen to conserve naturally occurring reduced ascorbic acid is described. During the first two days of storage it was shown that nitrogen-treated samples of milk lost reduced ascorbic acid at only one-third the rate of control samples.

Milk, as drawn from the cow, is a good source of reduced ascorbic acid, vitamin C, but during processing, storage, and distribution loses a significant portion of this essential nutrient. Accordingly, when milk is ingested by the ultimate consumer, it is rated as only a fair source of the antiscorbutic vitamin. Numerous investigators have accumulated data indicating that heat, light, and air destroy the reduced ascorbic acid in milk. Kon and Watson *(1)*, Krauss *(2)*, Diemair and Fresenius *(3)*, Washburn and Krauss *(4)*, Hand *(5)*, Holmes and Jones *(6)*, and others have pointed out that milk rapidly loses its reduced ascorbic acid when exposed to sunshine or bright light. Their findings indicate that fluid milk should be stored in darkness at low temperatures. Furthermore, experimental evidence reveals that reduced ascorbic acid in milk is destroyed by oxidation. Thus, any procedure for inhibiting oxidation should help to conserve the vitamin value of milk. This study was undertaken to determine the value of adding nitrogen to milk for preserving its reduced ascorbic acid content until the milk reaches the ultimate consumer.

EXPERIMENTAL

The milk for this study was obtained from the University Dairy Department. Part was produced by the University herd of cows, and part was purchased from commercial dairies. The milk from the 2 sources was thoroughly mixed and pasteurized by the holding method at 143° F. (61.7° C.) for 30 minutes in an 800-gallon stainless steel vat equipped with stainless steel paddles to keep the milk constantly agitated. After the milk had been cooled and bottled, sample bottles were taken to the laboratory. The samples were collected on 25 Monday mornings during the academic year. When the samples arrived at the laboratory, the milk was transferred to a large container and thoroughly mixed. Then it was placed in 1000-cc. cylinders, and nitrogen gas was led through a 3 mm. glass tube to the bottom of the cylinder at an estimated rate of 10 to 15 bubbles per second for fifteen minutes. One-half l. of the treated milk and a like quantity of control milk were placed in commercial flint glass quart bottles. Both the experimental and the control samples of milk were assayed for reduced ascorbic acid immediately and subsequently, at the end of four successive 24-hour periods. In the meantime, the experimental and the control samples were stored in a household type refrigerator in darkness at 10° C. (50° F.). Since the quart bottles were only half filled, the milk was stored under conditions similar to those frequently existing in the average home. The amount of reduced ascorbic acid in the milk when the samples were prepared and at the subsequent assay periods was determined by the Sharp *(7)* rapid method as modified by Holmes *(8)*.

[a] Contribution No. 858 of the Massachusetts Agricultural Experiment Station.

RESULTS AND DISCUSSION

Average values obtained for the reduced ascorbic acid content of the 25 control and 25 experimental milk samples at the 5 assay periods are reported in Figure 1. At the beginning of the experimental period, both the control and experimental samples contained an average of 18.2 mg. of reduced ascorbic acid per liter, but the amount in the control samples decreased rapidly during the first 2 days of storage, more than 60% of the initial amount of reduced ascorbic acid being lost. The rate of

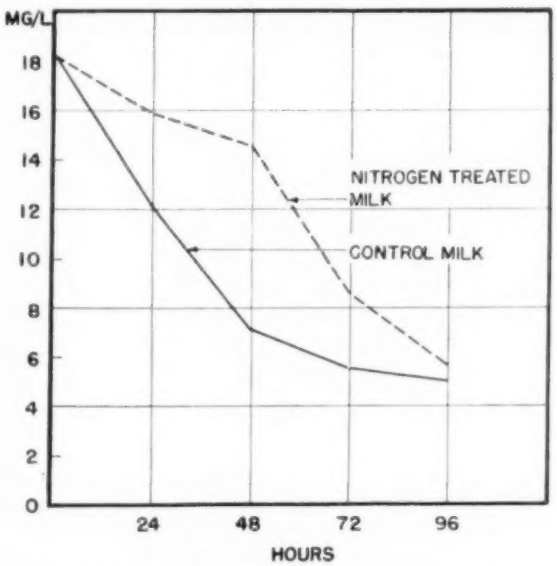

Figure 1. Value of adding nitrogen to milk to preserve its reduced ascorbic acid content.

loss of reduced ascorbic acid from the control milk samples was definitely less during the last half than during the first half of the storage period, and the final value was 5.0 mg. of reduced ascorbic acid per liter. The average daily loss of reduced ascorbic acid from the control samples was 33.5, 26.4, 8.8, and 2.6%, respectively, or a total of 71.3% loss for the four 24-hour periods during which the control milk was in storage. These values are similar to those previously reported by Holmes *(9)* in a comparison of the stability of reduced ascorbic acid in raw and pasteurized milk; namely, 31.0, 23.0, 14.0, and 9.0%, respectively, or a total of 77.0% loss of reduced ascorbic acid from pasteurized milk that was held in storage under the same conditions for 96 hours.

Nitrogen-treated milk retained its reduced ascorbic acid much better than the control milk during the first 2 days of storage; only about 20% was lost as compared with more than 60% for the control milk. During the

last half of the storage period, the rate of loss of reduced ascorbic acid from the nitrogen-treated milk was much more rapid, i.e., about 50% of the initial amount was lost during the second 48 hours of the storage period. The total loss of reduced ascorbic acid during the 96-hour storage period was similar for both the nitrogen-treated and control milk samples, being 70 and 73%, respectively. However, as already noted, the milk that was treated with nitrogen retained its reduced ascorbic acid for two days far more satisfactory than the untreated milk. Under normal conditions, a large amount of commercial milk is consumed within 2 days after it is processed. Thus, judged by the results of this study, treating milk with nitrogen could provide a means for conserving a large amount of naturally occurring reduced ascorbic acid.

SUMMARY

Samples of pasteurized, mixed herd milk were obtained from the University Dairy Department on 25 Monday mornings during the academic year. The samples were assayed for reduced ascorbic acid when they arrived at the laboratory and at 4 subsequent 24-hour periods. Between assay periods, the samples were stored in darkness at 10° C. (50° F.). The control samples lost reduced ascorbic acid rapidly and at approximately the same rate as in previous studies when milk was stored under similar conditions. During the first 2 days of storage the nitrogen-treated samples of milk lost reduced ascorbic acid at only one third the rate of the control samples. Since a large amount of commercial milk is consumed within 2 days after it is processed, treating milk with nitrogen could conserve a large amount of reduced ascorbic acid which occurs naturally in an extensively used food.

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Flavor of Sweet Potatoes as Affected by Certain Agricultural Chemicals Used as Insecticides

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(Manuscript received September 4, 1952)

Flavor evaluation of sweet potatoes grown with toxaphene, chlordane, DDT, and benzene hexachloride used as insecticides were made. After the sweet potatoes were baked, off-flavors were detected with some of the insecticides.

Undesirable off-flavors in a number of vegetables grown with agricultural chemicals to control insect infestation have been reported by various investigators *(1, 2, 3, 4, 5, 6, 7)*. In the present study, evaluation was made of the flavor and acceptability of sweet potatoes from experimental plots in which several insecticides and methods of application were tested against the sweet potato weevil, and of control sweet potatoes grown without the use of insecticides. The studies, cooperative with the Bureau of Entomology and Plant Quarantine and the Louisiana Agricultural Experiment Station, were made on sweet potatoes grown in Louisiana during 1951 on experimental plots of known history.

Four experimental samples were grown with toxaphene, chlordane, DDT, and technical benzene hexachloride as foliage treatments during the growing season. Two samples were grown in soil to which chlordane and technical benzene hexachloride were applied mixed with the fertilizer. Dosage varied with the insecticide (See Table 1). A check sample was grown without use of insecticides.

TABLE 1

Mean palatability scores for sweet potatoes grown with and without insecticides

Treatment	Total tech. chemical applied per acre	Absence of off-flavor*	General acceptability*
	lb		
Untreated check	0	4.9	4.6
Insecticide applied to foliage—6 applications:			
Toxaphene—20% dust	31	4.5	3.5
Chlordane—20% dust	26	4.5	3.9
DDT—emulsion spray	19	4.6	4.2
BHC—dust containing 5% of gamma isomer	56[b]	2.6	2.0
Insecticides applied to soil with fertilizer before transplanting:			
Chlordane	5	4.8	4.4
BHC—dust containing 6% of gamma isomer	17[b]	3.6	3.2

* Six judges scored each sample 4 times; the highest possible score was 5, lowest, 1.

[b] Approximate quantity of tech. BHC containing 13% of gamma isomer.

The raw potatoes, which were of fair quality when received at the Agricultural Research Center, Beltsville, Maryland, were sorted and the sound ones placed in one layer on trays and stored at 50° F. (10° C.) for a few days during the course of the tests for palatability.

PROCEDURE

Three sweet potatoes for each sample were baked at 425° F. (218.3° C.) until soft. Skins were removed from the potatoes after baking, and the potatoes for each sample were put through a ricer and mixed thoroughly. Samples were served warm on coded white plates to 6 experienced judges who rated them on 5-point scales on absence of off-flavor and on general acceptability. The highest possible scores of 5 denoted samples having no detectable off-flavor and very good general acceptability; scores of 1 indicated presence of very strong off-flavors and very poor general acceptability.

The design of the experiment was a balanced incomplete block; each experimental sample and the check sample used as a coded control were tested 4 times. At each judging session 4 samples were presented at 3-minute intervals. Judges were instructed to report any after-taste and to rinse their mouths thoroughly with distilled water after tasting a sample. The check sample was used at each judging session as a labeled reference sample to exemplify natural-flavored sweet potato. Palatability scores were analyzed statistically to aid in interpretation of results.

RESULTS

Mean scores for absence of off-flavor for sweet potatoes grown with the use of benzene hexachloride as an insecticide applied to the plant as a dust or to the soil with the fertilizer were significantly lower than those for sweet potatoes from an untreated plot or for sweet potatoes grown with toxaphene, chlordane, or DDT as insecticides. The sweet potatoes from plants dusted with benzene hexachloride had a significantly lower score (2.6) than that of the sample grown in soil with benzene hexachloride mixed with the fertilizer (score 3.6, Table 1). Flavor scores for the samples from plants on which toxaphene, chlordane, or DDT had been used and the sample grown in soil treated with chlordane could not be differentiated statistically from those for the check sample or from each other.

Both samples of sweet potatoes grown with the use of benzene hexachloride emitted a musty odor when cut open after baking, and several judges detected slightly strong to moderately strong musty off-flavors when they tasted these 2 samples. In addition, an off-flavor present in the sweet potatoes from plants dusted with benzene hexachloride was described by some judges as putrid, spoiled, or decayed. This off-flavor was found in all replicates of this sample.

Analyses for benzene hexachloride content by the Schechter-Hornstein method were carried out by the Division of Insecticide Investigations, BEPQ, on samples of the sweet potatoes grown with the benzene hexachloride dust and the benzene hexachloride soil treatment. No benzene hexachloride was found in sweet potatoes from dusted plants. In those from plants grown in soil treated with benzene hexachloride, analysis of 4 individual potatoes showed benzene hexachloride content varying from 0.3 to 1.2 p.p.m.

The fact that the sample which was found to have the most off-flavor showed no benzene hexachloride on chemical analysis raises a question as to the nature of the off-flavor. It is possible that the off-flavor was due to derivatives of benzene hexachloride, which were not determined by the method employed for benzene hexachloride, or that it was the result of some physiological change in the plant tissue caused by the benzene hexachloride dusted on the plants, or other causes.

Only barely perceptible off-flavors described variously as chalky, medicinal, earthy, or astringent were noted in the other experimental samples. Astringency was mentioned several times in comments on the sweet potatoes from plants dusted with chlordane; judges' notations on this sample also included the following: *acid, bitey, sour, stings mouth.* Similar flavor defects in foods produced with chlordane treatments have been noted by several other investigators *(2, 5, 7)*.

Acceptability scores were based on color and texture as well as flavor of the sweet potatoes. The untreated check sample was good to very good in acceptability, and the samples from soil treated with chlordane and from plants sprayed with DDT were almost as palatable as the check. Samples from plants dusted with chlordane were fairly good in acceptability. Judges rated them good in color, but other comments indicated lumpy or watery texture, lack of sweetness, and an astringent effect on the mouth.

Sweet potatoes from plants dusted with toxaphene were rated fair in general acceptability by the panel members, whose criticisms included lack of sweetness, bland pumpkin-like flavor, and granular texture. This acceptability rating may or may not have been the result of insecticide treatment.

Sweet potatoes from plants grown in soil treated with benzene hexachloride were considered only fair in over-all quality. The color of this sample was good and the texture was satisfactory, but the flavor, as mentioned previously, was poor.

Sweet potatoes from plants dusted with benzene hexachloride were poor in general acceptability. The color was dull and brown, and several judges called this sample inedible from the standpoints of both color and flavor.

These differences in general acceptability of the various lots of sweet potatoes may indicate that characteristics other than flavor may be affected by use of the different insecticides. Further research would be needed to investigate this possibility.

SUMMARY

Sweet potatoes grown with benzene hexachloride either dusted on the plants or used as a soil treatment had off-flavors which definitely impaired their eating quality and caused them to rate only fair to poor in general acceptability.

Only minor and nonsignificant differences among scores for absence of off-flavor were found in sweet potatoes from plants treated with toxaphene or chlordane dust or DDT emulsion spray or grown in soil treated with chlordane. With insecticide treatments in the amounts used, general acceptability of sweet potatoes from plants dusted with toxaphene was fair, from plants dusted with chlordane, fairly good, and from plants sprayed with DDT or grown in soil treated with chlordane, practically as good as that of sweet potatoes from untreated plots.

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Precooked Frozen Stews and Swiss Steak[a]

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(Manuscript received August 29, 1952)

Precooked beef stew, pork stew, and swiss steaks were stored with and without the addition of antioxidants at 0°, —10°, and —20° F. (—17.8°, —23.3°, and —28.9° C.). Storage time and temperature were apparently the important factors in the retention of the quality of these products.

Precooked frozen meats offer unlimited possibilities if an original high quality can be retained. Several factors such as packaging materials and methods, storage conditions, and methods of reheating have been shown to affect the quality of precooked frozen foods. Tinklin, Deck, Kalen, and Vail *(3)* have reviewed the literature on these subjects.

Watts and Peng *(4)* reported that cooked pork sausage kept better than raw sausage except at the upper limits of the normal pH range (pH 4.5-6.5) for fresh pork. Neither pH nor the presence of certain salts (sodium chloride, sodium nitrate, sodium acetate, magnesium chloride, potassium nitrate, potassium chloride, and sodium sulfate) had any effect on the development of rancidity in cooked sausage. In later work Watts, Peng and Kline *(5)* found odor and flavor of precooked frozen pork loin roasts and chops were less desirable after storage than the odor and flavor of roasts and chops stored without cooking. The precooked roasts were better than the postcooked roasts only from the standpoint of juiciness. Tinklin *et al. (3)* found that after 29 weeks of storage precooked frozen swiss steaks held at —10° F. (—23.3° C.) rated slightly higher in desirability of the fat than did steaks stored at 0° F. (—17.8° C.) or at 10° F. (—12.2° C.). Hanson, Winegarden, Horton, and Lineweaver *(1)* demonstrated that older chickens of good quality may be used as precooked frozen poultry products. Lineweaver, Anderson, and Hanson *(2)* added an antioxidant to the water in which turkey was simmered. The presence of the antioxidant during cooking had greater beneficial effect than the addition of the antioxidant after cooking, as judged by both peroxide values of the fat and scores for rancid off-flavor of the creamed turkey.

The study reported here was concerned with the effects of storage temperature, length of storage, and the addition of antioxidants on the quality of precooked frozen beef stew, pork stew, and swiss steak.

PROCEDURE

Precooked beef stew, pork stew, and swiss steak were packaged without the addition of an antioxidant and with the incorporation of the antioxidants NDGA (nordihydroguaiaretic acid), G-4 (propyl gallate, lecithin, and corn oil), and Tenox BHA (2-tertiary butyl-4-hydroxyanisole and 3-tertiary butyl-4-hydroxyanisole). The products were tested for acceptability when fresh, shortly after freezing, and after 3, 6, and 9 months' storage at 0°, —10°, and —20° F. (—17.8°, —23.3°, and —28.9° C.) with the exception of the beef stew stored at —20° F. (—28.9° C.) which was discarded because of a failure of refrigeration. Three samples of each variable were tested for palatability and 2 of these samples for free fatty acids and peroxide oxygen. Only one sample was used to test the fresh and fresh frozen products.

The meat for the beef stew and swiss steak was from a steer, carcass grade U. S. Good (low), which was ripened for 13 days between slaughtering and cutting. The round and blade steaks, sliced one inch thick, were used for the swiss steak.

Preparation of the stews. The beef and pork stews were prepared for the freezer in 12 cooking periods for each product. At each cooking period the following recipe was prepared twice.

BEEF OR PORK STEW

Meat cubes	1135 g.	Carrots	196 g.
Flour	28 g.	Onions	56 g.
Fat	56 g.	Celery	56 g.
Water	3 cups	Salt	18 g.
		Pepper	½ teaspoon

The meat cubes were dredged in flour and browned in hot fat (rendered suet or lard). The meat along with all the drippings was transferred to a pyrex casserole, water added, and the casserole covered. The stew was cooked for two hours in an oven at 350° F. The vegetables were added and cooking was continued for one half hour. The onion and celery were removed from the cooked stew, and if an antioxidant was to be used it was added at this time.

For the purpose of fixing antioxidant levels the stew was estimated to contain 25% fat, 20% in the meat and 5% added for browning purposes. The amounts of antioxidants used were based on previous work and on the recommendations of the manufacturers. The proportion of each antioxidant added to the assigned recipe of stew is given in Table 1.

TABLE 1
Antioxidant levels in the stew

Antioxidant	Estimated percentage of fat content	Approximate percentage of total weight	Weight per casserole of stew
Control (no antioxidant)	0.000	0.000	0.000
NDGA	0.012	0.003	38.0 mg. in 5 ml. hot fat
G-4	0.250	0.060	780.0 mg. in 25 ml. water
BHA	0.020	0.005	65.5 mg. in 5 ml. ethyl alcohol

After the antioxidant was added, the stew was stirred well and allowed to cool to 180° F. (82.2° C.) before packaging in Polyethylene plastic bags. The packaged stew was placed in the refrigerator until all packages for one lot (two recipes) were ready for freezing.

The yield from the 2 recipes of stew was 10 packages, each containing between 250 and 300 g. of stew, plus enough for a palatability test on the fresh product. One package from each lot of stew was used to test the product for palatability, free fatty acids, and peroxide oxygen shortly after freezing. The other nine packages were stored at the assigned temperature for 3, 6, and 9 months. Three packages were tested after each storage period. Three of the 12 lots of stew were packaged without an antioxidant, 3 with NDGA added, 3 with G-4, and

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3 with BHA. One lot for each treatment was stored at 0° F. (−17.8° C.), another at −10° F. (−23.3° C.), and the third at −20° F. (−28.9° C.).

The stews were reheated by placing the frozen package of stew in the top of a double boiler over boiling water for 1½ hours. After 45 minutes the stew had thawed sufficiently so that it could be removed from the bag and the mass broken up with a fork. Four samples of stew were presented at one time to a palatability committee of five members. The samples were scored according to Form I. (Figure 1). A fat sample com-

Product.....**Date**.....

Sample.....**Judge**.....

	Scores	1	2	3	4
Desirable 10-9	Appearance				
Moderately Desirable 8-7	Odor				
Acceptable 6-5	Flavor				
Slightly Undesirable 4-3	Tenderness				
Undesirable 2-1	Juiciness				
	Sauce				
	Comments:				

Figure 1. This is Form I, the score card used.

posed of visible fat pieces and sauce was taken from each reheated stew, frozen and held at −20° F. (−28.9° C.) until analyzed for free fatty acids and peroxide oxygen.

Preparation of the swiss steak. The swiss steak was prepared according to the following recipe:

SWISS STEAK

Beef	1262 g.	Salt	15 g.
Flour	75 g.	Pepper	⅛ teaspoon
Fat	80 g.	Water	2¼ cups

The meat was cut into serving-size pieces, dredged in flour, browned in hot fat (rendered suet), and then transferred to a pyrex casserole. The seasonings were added to the flour remaining from the dredging operation, and the mixture was added to the fat in the skillet. The water was added to make a gravy which was poured over the meat in the casserole. The meat was covered and cooked in an oven at 350° F. for two hours.

Two recipes of swiss steak were prepared at each of 12 cooking periods. Every 2 recipes yielded 10 packages, each containing a piece of steak weighing approximately 250 g., plus enough steak for a palatability test on the fresh product. The proportion and method of adding the antioxidants, packaging, reheating, and testing for acceptability were carried out in the same manner as for the stews.

The analyses for peroxide oxygen were done according to the method of Watts and Peng *(6)* with the exception of using ethylene chloride instead of carbon tetrachloride as the extraction solvent. An aliquot of the ethylene chloride fat extract was used to titrate free fatty acids in neutral alcohol.

RESULTS AND DISCUSSION

The average total scores for the different products are shown in Table 2.

Six factors—namely, appearance, odor, flavor, tenderness, juiciness and quality of sauce—were considered in the scoring (see Figure 1 for form used).

The scores for the freshly prepared products ranged from 57.8 to 54.0 for the beef stew, from 56.7 to 51.7 for the pork stew and from 55.0 to 50.0 for the swiss steak out of a possible score of 60. Although there was considerable range in scores, there is little evidence that the difference was due to the addition of antioxidants. Products tested a few days after freezing were scored lower than the freshly prepared product 32 out of 36 times. Only one lot scored as much as one point higher after freezing. In general, then it would seem that the processes of freezing, thawing and reheating tended to decrease the over all acceptability of the precooked meat products. Storage for 3, 6, or 9 months tended to decrease further the acceptability of the three products, whether stored at 0°, −10°, or −20° F. (−17.8°, −23.3° C., or −28.9° C.).

Loss in quality score averaged 4.7 points for the 3 products after storage for 3 months at 0° F. (−17.8° C.), 8.0 points after 6 months and 13.8 points after 9 months. Products stored at −10° F. (−23.3° C.) lost an average of 3.0, 4.9 and 9.8 points, respectively for the three periods. Results for the −20° F. (−28.9° C.) storage are less clear cut because of the loss of all beef stew stored at that temperature. However, the 2 products studied averaged a loss of 1.9, 5.5 and 9.9 points for 3, 6, and 9 months, respectively. The average loss for the pork stew stored 9 months was 15 points at 0° F. (−17.8° C.), 14 points at −10° F. (−23.3° C.), and 13.4 at −20° F. (−28.9° C.), whereas for swiss steaks it was 13.0, 7.3 and 6.5 re-

TABLE 2

Average total scores for beef stew, pork stew, and swiss steak *

Storage period and temperature	Beef Stew				Pork Stew				Swiss Steak			
	Cont.	NDGA	G-4	BHA	Cont.	NDGA	G-4	BHA	Cont.	NDGA	G-4	BHA
0° F.												
Fresh	54.8	56.4	57.0	54.0	52.2	51.7	54.4	52.3	52.3	54.2	50.4	52.5
Fresh Frozen	50.6	56.7	51.5	55.0	51.8	52.2	50.0	52.2	50.3	50.0	44.4	48.2
3 months	47.8	51.2	49.9	49.2	45.1	48.1	46.8	47.7	42.8	42.3	43.2	43.2
6 months	44.1	42.4	43.4	43.3	45.0	46.2	45.5	45.1	39.5	41.8	40.3	39.8
9 months	38.2	40.8	40.4	40.4	34.3	37.0	38.4	36.8	34.5	35.3	35.6	35.3
−10° F.												
Fresh	56.0	55.0	55.5	56.5	56.7	54.8	52.2	55.0	53.7	51.0	54.0	50.2
Fresh Frozen	50.8	53.4	52.5	53.8	52.3	50.8	51.6	50.0	44.2	48.0	49.6	49.8
3 months	50.0	50.5	50.2	50.8	47.6	47.9	48.8	49.5	42.4	42.5	44.9	45.6
6 months	45.2	47.7	48.3	46.8	46.5	46.0	45.3	48.0	41.4	42.8	46.3	44.1
9 months	44.9	44.9	46.3	45.4	34.0	38.3	38.0	37.8	38.1	40.8	42.3	41.4
−20° F.												
Fresh	57.8	56.1	56.3	56.3	53.2	52.8	55.0	52.7	54.0	50.0	52.5	55.0
Fresh Frozen	54.6	50.6	54.6	52.8	51.7	49.6	50.5	51.2	47.3	47.8	46.4	51.3
3 months					51.0	49.7	51.3	48.7	46.0	41.9	45.3	46.3
6 months					44.9	41.0	44.1	44.0	45.3	44.4	44.9	43.2
9 months					37.4	35.9	37.3	38.7	39.5	42.9	41.6	43.0

*Maximum score possible, 60.

spectively for the three temperatures. In this study the pork stews deteriorated in quality when stored 9 months, whether at 0°, —10°, or —20° F. (—17.8°, —23.3°, or —28.9° C.). On the other hand, the beef stew and swiss steaks retained quality much better at —10° F. (23.3° C.) than at 0° F. (—17.8° C.).

As the study was set up there was some evidence that G-4 had a certain beneficial effect at 0° F. (—17.8° C.) for all 3 storage periods. At —10° F. (—23.3° C.) and —20° F. (—28.9° C.) there was little evidence of beneficial effect that could be attributed to the use of antioxidants. Perhaps, the 2 lower storage temperatures were effective in preventing the type of deterioration affected by antioxidants for the 9 months of the study, so that any value derived from their use was not apparent in this time.

When palatability factors were considered individually, the fresh frozen products scored lower than the freshly cooked products the great majority of the time. In no instance was the aroma score higher for the frozen than for the freshly cooked product. Possibly a slight warmed-over odor was present even though not recognized as such by the palatability committee. With frozen storage there was a drop in score with each increase in storage period. Again the difference between 0° F. (—17.8° C.) and —10° F. (—23.3° C.) storage was much greater than between —10° F. (—23.3° C.) and —20° F. (—28.9° C.).

Flavor scores were lower for 32 of the 36 fresh frozen products as compared with the freshly cooked. The drop in score was as much as 1.9 points (of a possible 10) in one case and was more than one point in several instances. On the whole it was a few tenths of a point and all fresh frozen products were considered moderately desirable to desirable. (Form I). Only after storage for 9 months did products score less than 5 in flavor indicating that they might be falling below the point of acceptability. With two exceptions these products were stored at 0° F. (—17.8° C.). These 2 exceptions were both pork stews. After storage for 9 months the flavor scores for pork stews had dropped more than for the beef products, although the difference was slight at 0° F.

Analyses of variance were run on the flavor scores for each product. The effect of storage time was significant (5% level) for the beef stew and highly significant (1% level) for the pork stew and swiss steak. The effect of temperature, although showing a definite trend, was not significant for the beef stew and swiss steak but was significant (5% level) for the pork stew.

When flavor alone was considered, products containing G-4 did not show quite as great a drop in score when stored at 0° F. (—17.8° C.). At —10° and —20° F. (—23.3° and —28.9° C.) the average drop in score was about the same for the three products containing antioxidants and was slightly more for the controls at both storage temperatures.

After 9 months' storage at —10° and —20° F. (—23.3° and —28.9° C.) the pork stew had dropped more in flavor score than had the beef products. At —10° F. the drop averaged 1.7 for beef stew, 3.2 for pork stew and 1.4 for swiss steaks. At —20° F. (—28.9° C.) pork stews averaged 3.3 and swiss steaks 1.3. Apparently —10° F. (—23.3° C.) was as effective as —20° F. (—28.9° C.) in preserving quality in the products studied, up to 9 months' storage. It appeared superior to 0° F. (—17.8° C.) for the beef products stored for 6 months or longer, but apparently cooked pork like fresh pork has a limited storage life at all three storage temperatures.

Freezing and frozen storage had only a slight effect on tenderness scores, although after both 6 and 9 months storage, there was a trend toward a slightly lower score. Appearance, quality of the sauce, and juiciness factors were on the whole scored slightly lower after freezing and after frozen storage. The score for appearance changed only slightly with storage, for the sauce or gravy somewhat more, while there was a definite trend toward a drop in the juiciness score with increased storage time.

Peroxide oxygen was found in none of the samples analyzed. Small amounts of free fatty acids were found in all three products but there was no definite trend in acid numbers which could be associated with the presence of antioxidants, storage temperature or time, or palatability. Apparently deterioration within the limits of this study was not due to oxidation or hydrolysis of fat, and precooking probably excluded the possibility of enzymatic action. This may account for the fact that little benefit was evidenced from the use of antioxidants. On the whole, differences in quality were related to storage temperatures and time rather than the use of antioxidants.

SUMMARY

The effects of storage temperature, length of storage, and the addition of antioxidants on precooked beef stew, pork stew, and swiss steak were studied. All three products were packaged without the addition of antioxidants and with the incorporation of the antioxidants NDGA, Griffith's G-4, and Tenox BHA. The products were tested for palatability, free fatty acids, and peroxide oxygen when fresh, shortly after freezing, and after 3, 6, and 9 months of storage at 0°, —10°, and —20° F. (—17.8°, —23.3°, and —28.9° C.), with the exception of the beef stew stored at —20° F. (—28.9° C.), which was discarded because of a failure of refrigeration. All three products gradually decreased in desirability during the nine months' storage period. Under the conditions of this study storage time and temperature were apparently the important factors in the retention of quality in both the stews and swiss steaks. There was little evidence of any beneficial effect that could be attributed to the use of antioxidants. The appearance of the products was poorer and the meat became slightly less tender and less juicy as the storage time increased. The free fatty acid numbers were small and there was no peroxide oxygen in any of the samples analyzed.

Acknowledgments

Appreciation is expressed to the Refrigeration Research Foundation, Colorado Springs, Colorado, for financial support of this work and to Marjorie Barger and Armetta Watson for assisting with the palatability tests, chemical analyses, and organization of the data.

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Effect of Spray Materials on the Quality of Canned and Frozen Montmorency Cherries[a,b]

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(Manuscript received September 15, 1952)

A three-year study indicated that the spray materials, ferbam, nabam, copper, copper and wax and nabam and wax do not differ significantly in their effect on the quality of canned and frozen Montmorency cherries even though significant differences were found in the soluble solids contents of the canned cherries. Variation in the quality of processed cherries, however, does result from various cultural practices and climatic conditions during the growing season.

Investigations have shown that a wax emulsion applied to Montmorency cherry trees in combination with the usual fungicidal mixtures results in an increase in size of fruit of about 10 percent over those receiving no wax *(1, 2, 3, 5)* and therefore was considered of value for increasing fruit size and yield. However in 1947 cherry canners reported instances of inferior quality of processed cherries that could possibly be associated with the use of wax emulsion. They reported the cherries lacked color, were insipid, did not firm during cooling, were injured in pitting and retained spray residue. In 1949 Langer *(2)* and Langer and Fisher *(3)* found that ferbam and wax emulsion sprays increased the size, delayed ripening, lightened the color and decreased the soluble solids content of red cherries compared with sprays of proprietary coppers. Also the pitting characteristics were poorer and the drained weight of the canned fruit sprayed with either, or both, ferbam and wax emulsions was lower than those sprayed with proprietary copper. Swingle *(6)* has also reported that wax emulsions resulted in lower drained weights.

Since organic spray chemicals are now being widely used for controlling diseases of red cherries, it becomes important to know the effect of these materials on the yield and processing quality of the fruit. In 1949, 1950 and 1951 studies were made on Montmorency cherries to determine the relation of spray chemicals to the size, yield and soluble solids content of the harvested fruit and to the quality of the canned and frozen cherries. Results obtained on the canned and frozen cherries from the various treatments will be reported here. The results on the harvested fruit will be presented elsewhere.

EXPERIMENTAL METHODS

Montmorency cherries were obtained from 3 orchards in the Grand Traverse area and from one orchard in the Hart-Shelby area. In each orchard 4 pre-harvest fungicide applications were made. The fungicides used were ferbam,[c] nabam[d] and copper and were applied at the rates suggested by the manufacturer. All copper fungicide spray mixtures contained at least 70% metallic copper. The spraying operations were performed by each individual grower in the usual manner. Oil-wax emulsion[e] was included in the spraying schedules of insoluble copper and nabam in 3 orchards. The application was made at the time the cherries acquired the first tinge of pink. Five trees in each plot were selected and a mixed sample of fruit from these trees was obtained for processing at the time of commercial harvest. These cherries were immediately transported to the processing laboratory at East Lansing. On arrival they were placed in mesh bags, weighed and put in a 200-gallon soaking tank continually supplied with fresh tap water at the rate of approximately 25 gallons per hour and an average temperature of 42° F. (6° C.). The cherries were soaked for 12 hours, then removed, drained, weighed and sorted to remove damaged and light colored cherries. The sound fruit was pitted in a Dunkley cherry pitter of pilot plant capacity and the resulting loss in weight due to pits and juice recorded.

The pitted cherries were canned in No. 2 cherry enamel cans. Sixteen ounces of pitted cherries were filled in each can, covered with hot water, exhausted, processed in boiling water for 12 min., cooled and stored at 50° F. (10° C.). For freezing, the pitted cherries were packed with dry sugar (5 parts cherries plus one part sugar) in pint Marapak bags in cartons, frozen at −10° F. (−23° C.) and stored at 0° F. (−18° C.).

After 4 to 6 months' storage, the drained weight, soluble solids, tenderometer readings, color and grade of the canned and frozen cherries were determined. The canned cherries were removed from storage and allowed to come to room temperature, 68°-70° F. (20°-21° C.). The frozen cherries were thawed in warm water, 125°-130° F. (52°-54° C.) for about 20 minutes. Thawing was considered complete when the fruit reached a temperature of 50° F. (10° C.).

Drained weights and grades were determined according to the U. S. Standards for Grades for Canned and Frozen Red Sour (Tart) Pitted Cherries *(7, 8)*. The percent of soluble solids was determined with an Abbe refractometer. Tenderometer determinations were obtained with the Tenderometer using 150 g.

[a] Journal Article No. 1326 from Michigan Agricultural Experiment Station, East Lansing.

[b] A report of work done under contract with the U. S. Department of Agriculture and authorized by the Research and Marketing Act. The contract is being supervised by the Eastern Regional Research Laboratory of the Bureau of Agriculture and Industrial Chemistry.

[c] Ferric dimethyldithiocarbamate.

[d] Disodium ethylenebisdithiocarbamate.

[e] Dowax 222.

samples. The readings of the canned cherries were made on scale 1 and those of the frozen cherries on scale 2.

Color was measured using an Evelyn colorimeter with the 515 mμ filter. As previously reported (4) the color in the canned cherries was found evenly distributed throughout the fruit and drained juice, and hence color determinations were made only on the juice. However, in the frozen cherries it was found that the relatively rapid thawing method did not result in even distribution of the color throughout the fruit and drained juice. Therefore, representative samples composed of fruit and drained juice were blended in a Waring Blendor with an equal amount of water for 3 minutes. The juice was first filtered through ED No. 192 filter paper, then through Reeve Angel No. 812 filter paper. A known aliquot was diluted with Sorenson's citrate-hydrochloric acid buffer of pH 3.4 to give an optical density within the sensitive range of the colorimeter.

RESULTS

Results obtained during the 1949, 1950 and 1951 seasons are summarized in Tables 1, 2 and 3.

Loss of fruit due to cullage was similar for all spray treatments in orchards A, B and C of the Grand Traverse area and no significant differences were found between 1950 and 1951. In orchard D the cullage loss was significantly higher than in the other orchards. The high cullage might be explained, in part, by the fact that orchard D was the last to be harvested and the cherries, being more mature than those obtained from the other orchards, were more susceptible to damage during handling. This orchard had also been highly fertilized with nitrogen. Another orchard in this area, under similar spray treatments but harvested earlier, showed cullage losses similar to those obtained for orchards A, B and C.

The percent of light colored cherries removed during the sorting operation varied from 3.7 to 24.0. There was no correlation between the amount of light-colored cherries and the spray treatments. In 1951 orchard C had a significantly higher amount of light-colored cherries than the other orchards.

Pit losses from the cherries sprayed with copper were significantly higher than those sprayed with copper and wax and nabam and wax. Although the average pit loss of the copper sprayed cherries was greater than that from the ferbam and nabam sprayed cherries, the difference was not significant and showed considerable variation between orchards and years. The pit losses were significantly higher in orchard D than in the other orchards and were significantly higher in 1951 than in 1949 or 1950. In 1951 it was observed that the cherries were not as firm as in previous years and did not pit as readily. The processors in the Grand Traverse area also reported difficulties in handling the cherries this year and the difficulties were similar to those occurring in 1947. An examination of the weather data showed that the growing seasons of 1947 and 1951 were characterized by lower than normal heat accumulations during the months of May, June and July. This, therefore, suggests that the poorer quality of the cherries, as indicated by softness and poorer pitting characteristics, may be attributed, in part, to low growing season tempera-

TABLE 1

Effect of spray treatments on fresh, canned and frozen Montmorency cherries

	Ferbam	Nabam	Copper	Copper and Wax	Nabam and Wax	F Value	L. S. D. 5%	L. S. D. 1%
Fresh Fruit								
Cull fruit %	5.2	7.2	6.3	6.6	7.1	1.13		
Pit loss %	7.4	7.3	7.7	7.2	7.0	3.28*	0.4	0.6
Juice loss %	6.0	5.9	5.8	7.2	6.3	4.22*	0.8	1.1
Canned Fruit								
Soluble solids %	10.4	10.7	11.1	10.5	10.1	6.59**	0.5	0.6
Drained wt. oz.	13.8	14.1	14.1	13.9	13.8	2.5		
Color Density	3.67	3.95	3.77	3.71	3.35	2.24		
Tenderometer readings, lb./sq. in.	18.6	22.0	23.6	20.9	22.0	0.90		
Frozen Fruit								
Drained wt. oz.	9.7	9.8	9.9	9.4	9.5	1.78		
Color Density	5.45	5.96	5.85	5.28	5.16	1.45		
Tenderometer readings, lb./sq. in.	47.9	48.1	49.8	49.1	49.3	1.76		

*Significant 5% level.
**Significant 1% level.

TABLE 2

Effect of orchards on fresh, canned and frozen Montmorency cherries

	A	B	C	D	F Value	L. S. D. 5%	L. S. D. 1%
Fresh Fruit							
Cull fruit %	2.6	2.0	2.9	18.3	131.9**	2.3	3.3
Pit loss %	7.3	6.9	7.3	7.9	10.69**	0.4	0.5
Juice loss %	6.6	6.0	5.7	6.6	3.58*	0.7	1.0
Canned Fruit							
Soluble solids %	10.7	10.8	10.2	10.3	4.00*	0.4	0.6
Drained wt. oz.	13.9	13.9	14.0	14.0	0.10		
Color Density	3.34	3.31	3.39	4.72	27.88**	0.42	0.62
Tenderometer readings, lb./sq. in.	19.3	16.9	25.6	22.1	7.75*	4.3	6.3
Frozen Fruit							
Drained wt. oz.	9.6	9.7	9.2	9.8	3.23		
Color Density	5.11	4.92	5.35	6.78	10.71**	0.81	1.17
Tenderometer readings, lb./sq. in.	44.6	43.6	47.8	59.3	129.63**	2.1	3.0

*Significant 5% level.
**Significant 1% level.

TABLE 3
Effect of years on fresh, canned and frozen Montmorency cherries

	1949	1950	1951	F Value	L. S. D. 5%	L. S. D. 1%
Fresh Fruit						
Cull fruit %		6.7	6.2	0.59		
Pit loss %	7.3	7.1	7.6	5.45**	0.3	0.4
Juice loss %	6.9	5.9	5.9	7.96**	0.6	0.9
Canned Fruit						
Soluble solids %	11.1	10.2	10.4	14.41**	0.4	0.5
Drained wt. oz.	13.9	13.9	14.1	1.6		
Color density		3.80	4.08	36.00**	0.30	0.44
Tenderometer readings lb./sq. in.		22.8	19.3	7.08*	3.1	4.5
Frozen Fruit						
Drained wt. oz.		9.3	10.1	96.21**	0.2	0.3
Color density		4.28	6.80	103.57**	0.57	0.82
Tenderometer readings lb./sq. in.		45.3	52.4	123.94**	1.5	2.1

*Significant 5% level.
** Significant 1% level.

tures. Since the softness of the fruit occurred in all spray treatments in 1951, it appears that the spray material played a minor role, if any, in the lack of firmness.

Canned and frozen cherries. The soluble solids contents of the copper-sprayed canned cherries were significantly higher than those sprayed with ferbam, copper and wax, or nabam and wax. These results are in agreement with those reported by Langer and Fisher *(3)* and Swingle *(6)*. The soluble solids content of the cherries from orchard C were significantly lower than those from the other orchards. In 1949 the soluble solids contents were significantly higher than in 1950 or 1951. This would be expected since the growing conditions in 1949 were more favorable.

All the canned cherries met the minimum drained weight requirements of the U. S. standards for canned red, sour (tart) cherries *(7)*. No significant differences were found between spray treatments, orchards or years. The copper-sprayed cherries, however, averaged higher drained weights than the ferbam, copper and wax and nabam and wax sprayed cherries which is similar to results reported by Langer and Fisher *(3)* and Swingle *(6)*. The frozen cherries showed no significant differences in drained weights between sprays or orchards. The drained weights, however, were significantly higher in 1951 than in 1950. This trend was also observed in the canned cherries (Table 3), but the differences were not great enough to be significant.

Color densities were not significantly affected by the spray treatments but there was a tendency for the cherries sprayed with wax to have less color. The color densities of the cherries from orchard D were significantly higher than those from the other orchards. The greater color density may be attributed to the fact that the cherries were harvested at a more mature stage and that the percent sunshine and heat summation in the Hart-Shelby area was greater than in the Grand Traverse area. The color densities were also significantly greater in 1951 than in 1950. Increase in density was most pronounced in orchard D.

Tenderometer readings showed no significant differences between spray treatments but did show significant differences between orchards and years. The values obtained on the thawed frozen cherries were 2 to 3 times as great as those of the canned cherries. Although no definite explanation can be given, it appeared that in the freezing and thawing a greater disintegration of the cherry flesh occurred, resulting in the packing of the skins to give higher readings.

The quality of the processed fruit as judged by a taste panel showed no preference for any one spray treatment over another. There were, however, variations in the quality of the cherries from the different orchards and these variations differed from year to year. Investigations are now under way to determine the interaction of the fertilizers, soil moisture, temperature and time of harvest on the final quality.

SUMMARY

The effect of spray materials on the quality of canned and frozen Montmorency cherries was studied during 1949, 1950 and 1951.

The spray materials ferbam, nabam, copper, copper and one oil wax emulsion and nabam and one oil wax emulsion did not differ to any significant degree in their effect on the quality of the processed cherries. Significant differences between the spray materials only occurred in pit loss, juice loss and in the soluble solids contents of the canned cherries.

The cultural practices and climatic conditions generally resulted in greater variations in the processing quality of cherries than did the spray materials.

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8. U. S. Standards for grades of frozen red sour (tart) cherries. *Mimeo.* U.S.D.A., P.M.A. (June, 1949).

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BRANCHES IN OTHER PRINCIPAL CITIES OF THE U. S. A. AND THROUGHOUT THE WORLD

Abstracts

(Continued from page 16 preceding technical papers)

Acid solvents, e.g. isopropanol (70), water (30), trichloroacetic acid (5) (in which cases the paper is first washed with an alc. soln. of 8-hydroxyquinoline) or/and alk. solvents, e.g. isopropanol (40), isobutanol (20), water (39), and concd. aq. NH_3 (1) (in which cases the paper is first washed with dil. HCl), may be used; R_f val. are given for five systems of solvents. The procedure will detect 5 μg. of P, when the chromatogram is tested by the method of Hanes and Isherwood.

Use of the titers of fatty acids for the analysis of binary and tertiary mixtures.

Paquot, C. *Bull. mens. ITERG.*, *6*, 174-8 (1952); *J. Am. Oil Chemists' Soc.*, *29*, 434 (1952).

The titers of a series of binary and tertiary mixts. contg. lauric, myristic, stearic, oleic, and linoleic acids are given on 11 charts. With these values and the acid nos. it is possible to det. the compn. of tertiary mixts. of the satd. acids. The systems contg. unsatd. acids, palmitic-stearic-oleic and stearic-oleic-linoleic, are detd. by their titer and iodine value.

Applications of an automatic Karl Fischer titrator to moisture determinations in food products.

Frediani, H. S., Owens, J. T., and Baird, J. H. *Trans. Am. Assoc. Cereal Chemists*, *10*, 176-80 (1952).

The Karl Fischer technic for the detn. of moisture is widely applicable to the food inddustries. The use of an automatic titrator eliminates most of the "art" involved in this technic, permits rapid and reproducible water detns. by relatively inexperienced personnel, and enables results to be obtained in a matter of minutes, rather than hours. The samples tested in this study are representative of the wide field of applicability of this method.

The analysis of meat products. Method recommended by the Society of Public Analysts and other analytical chemists for the analysis of meat products in relation to the meat products order, 1952.

Analyst, *77*, 543-4 (1952).

Includes water, fat, nitrogen, ash and starch detns.

BIOLOGICAL SCIENCES

BIOCHEMISTRY

Studies on protein hydrolysis. I. Preliminary observations on the taste of enzymic protein-hydrolysates.

Murray, T. K., and Baker, B. E. *J. Sci. Food Agric.*, *3*, 470-8 (1952).

The influence of various factors such as type of protein, extent of hydrolysis and nature of enzyme prepn. on the development of undesirable flavors in enzymic protein-hydrolysates has been investigated. Of the proteins studied, gelatin gave the blandest-tasting product and casein gave the most objectionable one. The type of proteolytic enzyme used was shown markedly to affect the taste of the resulting products.

Studies of the reaction between proteins and reducing sugars in the "dry" state. V. The reactions of D-galactose, 2-deoxy-D-galactose, D-glucosamine and N-acetyl-D-glucosamine with casein.

Lea, C. H., and Rhodes, D. N. *Biochim. Biophys. Acta.*, *9*, 56-60 (1952).

2-deoxy-galactose and 2-amino-glucose (glucosamine) both produce much more rapid browning with casein at pH 6.3, 37° C. and a water content corresponding to a relative humidity of 70% than do galactose or glucose. The reaction of glucosamine with casein differs fundamentally from that of glucose. The glucosamine amino groups disappear rapidly and discoloration and insoly. of the protein develop, but the protein amino groups appear not to be involved in the primary reaction.

Action of carboxypeptidase on tobacco mosaic virus.

Harris, J. I., and Knight, C. A. *Nature*, *170*, 613-14 (1952).

By means of paper chromatography, it was shown that only threonine was released by the action of carboxypeptidase on tobacco mosaic virus. The amt. released equalled 7% of the threonine content of the virus. Full virus infectivity was retained in the modified virus. The modified virus reproduced as the unmodified form from which 7% of the threonine could be obtained by enzyme action.

Difference in the starch-splitting activity of saliva in male and female mice; its hormonal conditioning.

Raynaud, J., and Rebeyrotte, P. *Compt. Rend. Acad. Sci.*, *228*, 433-5 (1949); *Biol. Abstracts*, *26*, 2709, No. 30525 (1952).

The amylase activity of the saliva of male mice is about 50% higher than that of female mice. Testosterone propionate administered to female mice causes an increase in amylase power of saliva as much as 30%.

A new amino-acid with the groundnut plant (Arachis hypogaea): evidence of the occurrence of γ-methyleneglutamine and γ-methyleneglutamic acid.

Done, J., and Fowden, L. *Biochem. J.*, *51*, 451-7 (1952).

A ninhydrin-reacting component of the groundnut plant giving an orange-brown spot (R_f = 0.66 in ammonia-phenol) is described. The new compd. is a normal metabolite of the plant. Isolation and identification procedures are presented in detail. The tentative identification appears to be γ-methylene-glutamine and/or γ-methyleneglutamic acid.

Effect of vitamin B_{12} on the body composition of rats.

Ling, C. T., and Chow, B. *J. Biol. Chem.*, *198*, 439-43 (1952).

Results indicated that vitamin B_{12} played a role in carbohydrate or fat metabolism rather than in protein metabolism. Growth rate was also enhanced and food intake increased when B_{12} was given to rats deficient in the vitamin.

Vitamin A to protect arteries of diabetics.

Science News Letter, *62*, 198 (1952).

Rats with diabetes cannot convert carotene into vitamin A as efficiently as normal, non-diabetic rats. If applicable to human beings these findings indicate that vitamin A supplements may be required in the diets of diabetics. This may also be a first step toward the discovery of an agent to control the premature aging of the arteries found in diabetics.

Vitamin C essential for anti-arthritis cortisone.

Science News Letter, *62*, 185 (1952).

Guinea pigs lacking vitamin C develop scurvy and severe arthritis. Cortisone prevents the arthritis while ACTH does not. ACTH acts by stimulating the adrenal gland to produce cortisone. Evidently, from the guinea pig studies, the gland cannot do this even under ACTH stimulation when it lacks vitamin C.

Relief of hypoglycaemic convulsions with butyric acid.

Potter, B. J. *Nature*, *170*, 541 (1952).

Lambs in hypoglycaemic convulsions were given intrajugular injections of sodium butyrate. Convulsions ceased, with an accompanying rise in blood sugar. Similar results were obtained with adult sheep and rabbits. It is suggested that butyric is converted to glucose *in vivo*.

A new antifertility factor.

Sieve, B. F. *Science*, *116*, 373-85 (1952).

Animal and clinical evaluation of phosphorylated hesperidin as an antifertility factor is reported.

MICROBIOLOGY

Erythromycin—a new antibiotic.

What's New, 9-10, November, 1952.

Erythromycin is a new antibiotic of low toxicity which is effective orally against a wide variety of organisms, particularly gram-positive bacteria but also against *H. pertussis*, *H. influenzae*, corynebacteria and certain large viruses. Erythrocin is also effective against organisms which have become resistant to the action of the other antibiotics. It is produced during the growth of *Streptomyces erythreus*. One of the advantages of Erythrocin from the point of view of side effects, as compared with the other antibiotic, is that a lower incidence of toxic reactions is to be expected because erythromycin does not decrease the intestinal population of *E. coli*. There may be consequently less tendency for markedly abnormal intestinal flora to occur.

(Continued on page 22)

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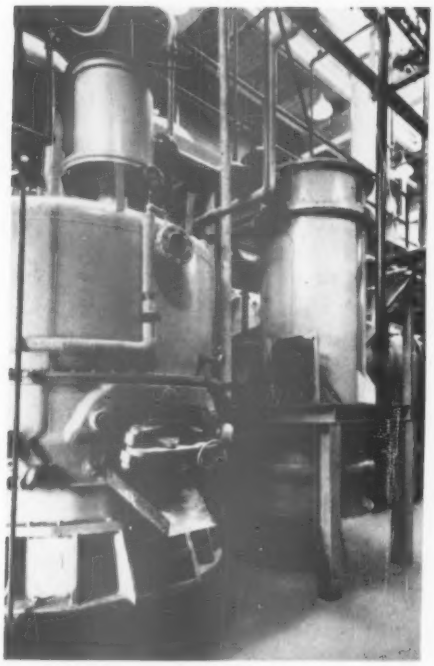

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Another triumph of Griffith research—devoted solely to better food processing

Abstracts

(Continued from page 20)

An inexpensive fermentometer.

McCLARY, D. O., PALLEROSI, N. P., AND LINDEGREN, C. C. *Wallerstein Lab. Communs., 15,* 219-22 (1952).

An inexpensive fermentometer is described by means of which simultaneous fermentation can be followed in a large number of different vessels. Diagrams and equations for calibrations and flask contents are given.

The rate of endogenous respiration as affected by the oxidation of exogenous substrates.

BLUMENTHAL, H. J., KOEFLER, H., AND GOLDSCHMIDT, E. P. *Science, 116,* 475-7 (1952).

Many manometric data are corrected on the basis that endogenous respiration continues at normal rate owing to simultaneous oxidation of exogenous substrate. This assumption is not necessarily valid. Rate of release of labeled CO_2 from labeled resting cells in presence and absence of unlabeled substrates can be used to test the validity of assumption. This paper illustrates some of the difficulties encountered in the use of this method.

NUTRITION

Nutritional evaluation of food proteins by measuring availability of amino acids to microorganisms. I. Cottonseed proteins.

HORN, M. J. *J. Nutrition, 48,* 231-41 (1952).

It has been demonstrated that various methods of processing cottonseed meals alter the nutritional value of the protein. Two methods of evaluating these meals were used, the rat assay method, which showed that the nutritional value of these meals for the rat was considerably altered by the processing, and the microbiol. method, which showed that the changes in nutritional value were due to a change in the availability of the amino acids. Different methods of processing affected the availability of different amino acids. The assay of acid hydrolysates showed that only very severe temps. and pressures caused any destruction of the amino acids. Comparison of results from assays of acid and enzyme hydrolysates by the microbiol. method showed that, although the amino acids were present, some of them were bound in such a way that they were no longer available to the microorganism. An enzyme digestion system has been worked out which appears to give good reproducibility of results; the availability of the digestion products to the microorganisms correlated well with the results of rat feeding.

Effect of the level of fat in the diet on the growth performance of dogs.

SIEBLER, A. J., AND SCHWEIGERT, B. S. *J. Nutrition, 48,* 81-90 (1952).

The rate of gain of young cocker spaniel pups fed diets comprised of ingredients commonly used in dry meals, with or without added fats (choice, white grease stabilized with antioxidants), was investigated. The rates of gain for a 10-week period, when 4, 6, or 8% fat was added to the basal diet or when 6% fat was added to a corn meal, were equal or slightly superior to those obtained when the diets without added fat were fed. No significant differences in the food or caloric efficiencies were noted between the groups fed different levels of fat, which indicated that the calories from the fat were well utilized. The performance of groups fed sucrose (equivalent in crude calories to the added fat) was comparable to that of groups fed the basal diet. It is concluded that 4, 6, or 8% stabilized fat can be successfully added to the expt. ration used in these expts. as judged by rates of gain, food utilization and the general health of young cocker spaniel pups.

The effect of dietary fat and caloric restriction on protein utilization.

ROSENTHAL, H. L. *J. Nutrition, 48,* 243-55 (1952).

The expts. demonstrate that the incorporation of large amts. of fat in the diet does not alter the utilization of dietary protein when the caloric intake is at an optimal level. Nitrogen utilization may be reduced, however, when large amts. of fat are fed in conjunction with diets restricted in calories and protein. The addn. of large amts. of protein to calorically deficient diets results in the use of some of the protein for energy purposes but prevents an increased excretion of nitrogen caused by high fat diets. The av. dog can digest large amts. of protein and fat, but digestibility of fat decreases with depletion of body protein. When dogs are subjected to caloric deprivation, they may be maintained in positive balance for variable lengths of time provided the quantity of dietary protein is sufficient and the caloric reserves of the body are adequate. Continued caloric restriction, however, eventually leads to marked loss of wt. and an increase in the excretion of body and dietary nitrogen assocd. with severe tissue destruction.

The liver in obesity.

ZELMAN, S. *J. Am. Med. Assoc., 150,* 1246 (1952).

The liver damage in obesity may be explained by (a) the high caloric requirement of obese persons, constituting a functional overload on the liver; (b) the high-carbohydrate, high fat, low protein diet customary among the obese; and (c) the increased requirement of choline and vitamins of the B complex imposed by the quant. and qual. nature of the obesity diet. The reducing program should consist of a high protein diet supplemented by choline and vitamins of the B complex.

Dermatosis in weanling rats fed lactose diets.

SCHREIBER, M. *J. Nutrition, 48,* 125-37 (1952).

A dry, scaly dermatosis was observed on the paws of weanling albino rats fed a mineralized milk or purified lactose diet. The max. degree of scaliness occurred in 10 to 12 days followed by a spontaneous recovery in an addnl. 2 to 3 weeks. The seasonal variation in the degree of dermatosis has been shown to be the result of seasonal changes in the relative humidity of our animal room rather than differences in summer and winter milks. Relative humidities above 50% prevented scaliness; decreasing values increased the severity of scaliness. The purified lactose diets contg. corn oil or coconut oil induced the most pronounced scaly dermatosis and diarrhea; replacement of these plant fats with butterfat or lard alleviated the dermatosis and diarrhea. Substitution of sucrose or a galactose-glucose mixt. for lactose in the corn oil diet prevented the occurrence of dermatosis and diarrhea. The supplementation of ½ to 1 g. of fresh beef liver per rat per day provided definite protection against the lactose-induced (milk-induced) dry, scaly dermatosis when administered within a relative humidity range of 25 to 45%. Liver was more effective as an anti-dermatosis agent when supplemented than when incorporated in the purified lactose diets.

ENGINEERING

A new concept for rust prevention.

EASLEY, W. *Monsanto Mag.,* 16-18, October/November, 1952.

Shell Development Co. has developed a new product called Vapor Phase Inhibitor (VPI) which affords greater protection, reduces costs and is more convenient than any older method of rust prevention.

Ion exclusion discovery offers new industrial removal method.

Ind. Labs., 3, 18-19, November, 1952.

Making use of ion exchange materials, but not requiring a regenerating chemical, the new method seps. a non-ionic from an ionic substance by introducing their soln. into a bed or column, then rinsing with pure water. The non-ionic substance, for example, methanol, permeates the resin beads, hence must pass through them and around them. The ionic, for example, salt, is excluded by the resins, flows around, but not through the beads, hence passes through faster, and is rinsed out ahead of the non-ionic substances.

FOOD AND FOOD TECHNOLOGY

The nutritive value of fish meal and condensed fish solubles. IV. A comparison of herring meals made by drying herring press cake commercially and experimentally at a lower temperature.

BIELY, J., MARCH, B. E., AND TARR, H. L. A. *Progress Reports of the Pacific Coast Stations, No. 90,* 10-13 (1952); *Comm. Fisheries Abstracts, 5,* 1, December, 1952.

In previous studies in this series, the authors found that herring meals, air-dried at 100 to 110° F., had a higher nutritive

(Continued on page 24)

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Abstracts

(Continued from page 22)

value for the chick than did herring meals dried commercially. The meals used in the earlier studies were not however, strictly comparable with one another because they were not prepd. from the same press cake. In the present work, this variable was removed. In test 1, two exptl. meals dried at low temp. promoted faster growth than did two corresponding com. meals. Thus, this expt. showed conclusively that some nutritive factor is rendered unavailable to the chick by the com. drying process. Tests 2 and 3 were designed to show whether the limiting factor in the com. meal was one of the known vitamins. When a mixt. of the known vitamins was added to the low temp. dried meal, there was no improvement in growth rate, however, a marked improvement with the commercially dried meals occurred. This was interpreted to mean that the herring meal dried at low temp. contained adequate quantities of one or more vitamins that are markedly deficient in the commercially dried meals. It was assumed from this that some heat-liable vitamin(s) was presumably destroyed or rendered unavailable by the normal flame-drying procedure employed in the manuf. of com. herring meal. When the authors fed the different meals supplemented with both the vitamin mixt. and penicillin, no addnl. response was found to penicillin over that obtained with the vitamin supplement alone in the rations contg. 17% protein. This agreed with previous findings from the Poultry Nutrition Laboratory of the University of British Columbia that max. response to antibiotics is obtainable only with rations supplying optimum amts. of protein. Results obtained, on the other hand, by the addn. of penicillin to the vitamin supplemented rations contg. 21% protein, where the protein level was not a limiting factor, were somewhat unexpected. Only with the ration contg. the normal com. meal was there a response to the antibiotic. With the 21% protein rations supplemented with the vitamin mixt. and penicillin, the best rate of growth was obtained with the overheated meal, followed by the normal com. meal, with the low temp. dried meal giving the slowest growth. In this connection, it is interesting to note that earlier expts. had indicated that the nutritive value of herring meals dried at low temp. might be improved by heat treatment.

Entomologist develops quick way to count insect-damaged wheat kernels.

Agr. News Letter, 20, 84, September/October, 1952.

A simple aid in dctg. hidden insect infestation of wheat has been developed. A 100 g. sample of wheat is placed in a flat-bottomed pan 7" wide and 3" deep. A pint of a 2% soln. of ferric nitrate in water is poured over the wheat. The ferric nitrate causes the damaged kernels to float. The contents are swirled in the pan for 30 sec. The weevil-damaged kernels float to the surface, and they can be lifted out of the pan onto a piece of blotting paper, where they can be counted. Since warehousemen sometimes reject farm-stored grain that obviously is in bad condition, the farmer may, if he wishes, use this test on his grain beforehand, to det. the % of infestation.

Cacao polyphenolic substances. I. Fractionation of the fresh bean.

Forsyth, W. G. C. *Biochem. J., 51,* 511-16 (1952).

The polyphenolic components in exts. of fresh cacao beans have been examd. by paper strip chromatography. At least eleven polyphenols are present and have been sepd. on columns of cellulose pulp. In forastero (purple) beans there are two main anthocyanins with also a trace of a third pigment, with the properties of a cyanidin diglycoside. The two main pigments are a cyanidin monoglycoside and a cyanidin pentose glycoside, the sugar radicals being resp., glucose and glucosearabinose. A sugar-free leucocyanidin and a mixt. of leucocyanidin glycosides are also present. There are at least six catechin-like substances of which epicatechin is the main component. From chromatographic comparison, catechin, epigallocatechin and gallocatechin, would appear to be present. The chem. similarity between different species and varieties of beans used in chocolate manuf. is striking.

Effect of incipient enzymatic proteolysis on the viscosity and heat stability of evaporated milk.

(Continued on page 26)

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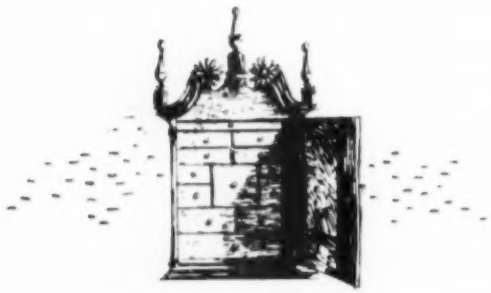

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Abstracts

(Continued from page 24)

TARASSUK, N. P., AND NURY, M. S. *J. Dairy Sci., 35,* 857-67 (1952).

Proteolytic enzymatic treatment of evapd. milk within the limits of what generally is regarded as the first phase of enzyme action increases the viscosity of evapd. milk upon its sterilization. Enzymatic treatment lowers the stability of milk to heat. The state of milk proteins as affected by incipient proteolysis is a factor in the stability of milk to heat in addn. to the factor of salt balance. The viscosity of evapd. milk with relatively high stability to heat can be increased to max. (more than doubled) by enzymatic treatment without deleterious effect on color or flavor of milk, as contrasted to the common method of increasing viscosity by addnl. cooking in the process of sterilization. The method of increasing viscosity of evapd. milk by enzymatic treatment prior to sterilization is applicable to both the standard and short-time high temp. sterilization processes, but enzymatic activity in the case of HTST process has to be greater to obtain the same increase in viscosity. Milk destabilized to heat by enzymatic treatment can be made stable to heat again by the addn. of such stabilizing salts as Na_2HPO_4. The effects of incipient proteolysis with respect to viscosity and heat stability of milk are explained in the light of the Linderstrom-Lang theory of denaturation as the mechanism of initial enzyme action in globular protein systems. The results of the present study and other phenomena affected by an incipient proteolysis of milk proteins, such as the inhibition of development of oxidized flavor, lowering of curd tension and increased water sorption, can be adequately explained on the assumption that denaturation is an initial reaction in proteolysis. Since all above phenomena can be produced as well by the heating of milk, it is advanced that enzymatic denaturation of the proteins in milk is similar in its major respects to heat denaturation, i.e., the breaking of ionic and hydrogen bonds through which the peptides are linked, thus permitting the coiled peptide chains to uncoil.

Grow seedless tomatoes in weedless gardens.

Science News Letter, 62, 223 (1952).

Compds. made from the weed killer, 2,4-D and the l-form of amino acids stimulate the growth of tomatoes, resulting in larger sized tomatoes without seeds. So far 12 of the 22 or 23 known amino acids have been tried, all with success. Present tests have been done under greenhouse conditions. Field tests will be required before com. application can be made.

Essential oils as vapour phase antiseptics against mold fungi.

GALLOWAY, L. D. *Perfumery Essent. Oil Record, 43,* 359-95 (1952).

Remarkable effectiveness is claimed for vapor phase antiseptics as inhibitors of mold growth, the effectiveness being independent of and usually much higher than the effectiveness of some materials in the solid or liquid phase being protected. Effective materials claimed range from volatile formaldehyde and acetaldehyde, thru less volatile higher aldehydes such as higher aldehydes, thymol and essential oils to such low volatiles as vanillin. It is suggested that since effective compds. are the types found in essential oils, an odorless essential oil would be useful for protecting food stuffs.

Application of urea complexes in the purification of fatty acids, esters, and alcohols. I. Oleic acid from inedible animal fats.

SWERN, D., AND PARKER, W. E. *J. Am. Oil Chemists' Soc., 29,* 431-4 (1952).

Urea complex formation has been employed in the prepn. of purified oleic acid (oleic acid content 80-95%) from various grades of inedible animal fats and red oils. Since the urea complex of oleic acid forms in good yield at room temp., low temps. are not required in the isolation procedure. Yields of oleic acid are equal to or lower than those obtained by conventional low-temp. crystn. procedures, but the prepn. of a polyunsatd. free oleic acid is apparently not possible by urea complex formation alone. The sepn. of polyunsatd. acids from oleic acid by urea complex formation is more convenient than but not as efficient as by solvent crystn., but sepn. of satd. acids from unsatd. acids

(Continued on page 28)

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Abstracts

(Continued from page 261

is less convenient. Advantages and disadvantages in using urea in the prepn. of purified oleic acid are briefly discussed.

The conidendrols as inhibitors of oxidation and polymerization.

MACK, C. H., AND BICKFORD, W. G. *J. Am. Oil Chemists' Soc.*, *29*, 428-30 (1952).

Alpha and beta conidendrol have been tested and intercompared with accepted antioxidants for the prevention of rancidity development in fats, oils and fat-contg. candies. On the basis of the data reported here it may be concluded that the conidendrols are apparently equal or superior to other stabilizers in current use. In addn., the conidendrols are produced from a raw material which is in abundant supply.

PATENTS (U. S. A.)

Retarding the staling of bakery products.

STONE, I. Assignor to Wallerstein Co. 2,615,810, October 28, 1952.

The process of making bakery products having inhibited staling qualities which comprises incorporating in a dough a heat-stable alpha amylase enzymatic prepn. in amts. equiv. to from 0.1 to 4 SKB alpha amylase units per 100 g. of flour in the dough, the enzymatic prepn. being of such thermal stability that effective amts. of alpha amylase enzyme are present and active in the crumb at temp. above the starch gelatinization point, and thereafter baking the dough.

Method of preparing corn for popping.

SMITH, H. C. Assignor to American Pop Corn Co. 2,614,044, October 14, 1952.

A method prepg. popcorn for popping which comprises storing a quantity of freshly harvested popcorn ears under shelter but freely exposed to atm. air throughout the quantity for a period of time including the spring months to induce a curing of popcorn evidenced by the generation of heat, the atm. exposure and the generation of heat both serving to reduce the original moisture content of popcorn, sufficiently turning over the quantity of popcorn during the generation of heat to maintain uniform temp. in popcorn whereby uniform drying and curing of the entire quantity of popcorn is promoted, continuing the storage until the moisture content of popcorn has been reduced from between 16% to 18% to between 12.7% to 13.5% continuing the storage after the reduction in popcorn moisture content whereby the moisture is maintained between the 12.7% and 13.5% without loss of desirable popping qualities thereafter shelling the popcorn while it still has substantially reduced moisture content and while such moisture content is still uniform throughout the quantity of popcorn, and packaging the shelled popcorn kernels in moisture proof containers.

INDUSTRIAL CHEMISTRY

Features of new patent law.

GRAY, A. W. *Am. Perfumer, Essent. Oil Rev.*, *60*, 183-4 (1952).

Important changes incorporated in the new patent statute (Public Law 593) are: 1. New use of a known compd., process, or machine may be patented; 2. Matter disclosed in an application for a patent, but not covered by the patent itself, is not patentable by others. 3. A patent may not be granted if the subject matter represents only a difference from the prior art obvious to one skilled in that art. 4. An assignee or one with sufficient proprietary interest may apply for and be granted a patent if the inventor cannot or will not apply himself. 5. Application for a reissue must be made within two years of the grant of the original patent. 6. Anyone who actively induces or promotes infringement of a patent is as liable as is the infringer.

Control systems.

BROWN, G. S., AND CAMPBELL, D. P. *Sci. American*, *187*, 57-64, September, 1952.

A general discussion of the application of feedback mechanism. Some existing systems are described, possibilities for the future are explored, and the next steps toward realizing these possibilities are indicated.

ORGANIC CHEMISTRY

The action of formaldehyde on proteins. Part. III. The hydrolysis of formaldehyde-hardened proteins by enzymes.

HAWORTH, R. D., MACGILLIVRAY, M., AND PEACOCK, D. H. *J. Chem. Soc.*, 2981-7 (1952).

It has been found that certain proteins treated with formaldehyde under acid conditions can be hydrolyzed by papain and the products further hydrolyzed by trypsin. From the hydrolysate from "Ardil" protein fibre, six formaldehyde contg. fragments have been isolated. Acid hydrolysis has shown that aspartic and glutamic acid and at least three other amino-acids are assocd. with these six formaldehyde contg. fragments. The results suggest (1) that N-methylene-bisamide derivs. of aspartic and glutamic amides play a considerable part and (2) that lysine and arginine play little if any, part in the reaction of proteins and formaldehyde under acid conditions.

Some reactions of sugars catalyzed by a cation-exchange resin.

WADMAN, W. H. *J. Chem. Soc.*, 3051-5 (1952).

Amberlite I. R.-120 has been shown to be effective as a catalyst for the formation and hydrolysis of certain sugar glycosides and isopropylidene derivs. In the hydrolysis of maltose and sucrose the rates were appreciably slower than with equiv. sulfuric acid; in the hydrolysis of sol. starch the rate was about one-twentieth.

PACKAGING

Adhesives, 2. Synthetic products.

HARRISON, K. H. *Mfg. Chemist*, *23*, 365-70 (1952).

Synthetic adhesives, which consist essentially of the same synthetic resins which are used in the plastics industry, have advantages over natural glues. They can be made of uniform quality and are highly resistant to moisture and to fungal attack. There are two main classes: thermoplastic, which includes the vinyl polymers, modified rubber and cellulose esters and ethers, and thermosetting, which includes phenolic, urea-formaldehyde, alkyl, furfural and silicone resins. The mfg. properties and uses of these highly efficient adhesives are discussed.

PATENTS (U. S. A.)

Method of coating foods with pectinate or pectate films.

OWENS, H. S., AND SCHULTZ, T. H. Assignors to the U. S. A. 2,611,708, September 23, 1952.

The process of encasing foods with an edible film envelope which comprises coating the food with a soln. contg. a member of the group consisting of alkali low-methoxyl pectinates and alkali pectates, contacting the coated food with a soln. contg. calcium ions to gel the coating, then drying the gel coating to form the film.

Method of making a cold-mixing food starch powder.

HALDEN, A. A. Assignor to National Starch Products, Inc. 2,613,150, October 7, 1952.

The method of making a cold-mixing food starch powder, which consists in pretreating a starch selected from the class consisting of potato, tapioca and waxy maize to produce an inhibited starch, i.e., a starch characterized by the property that when mixed with water and subjected to normal gelatinizing conditions the bursting of the starch granules will be inhibited and characterized by a reduction of the natural rubbery cohesiveness of the starch when in a gelatinized state, in subjecting inhibited starch in an aq. medium to the steps of gelatinization, drying on heated drums and comminuting the drum dried starch powder, and in adding sugar to and dissolving the sugar

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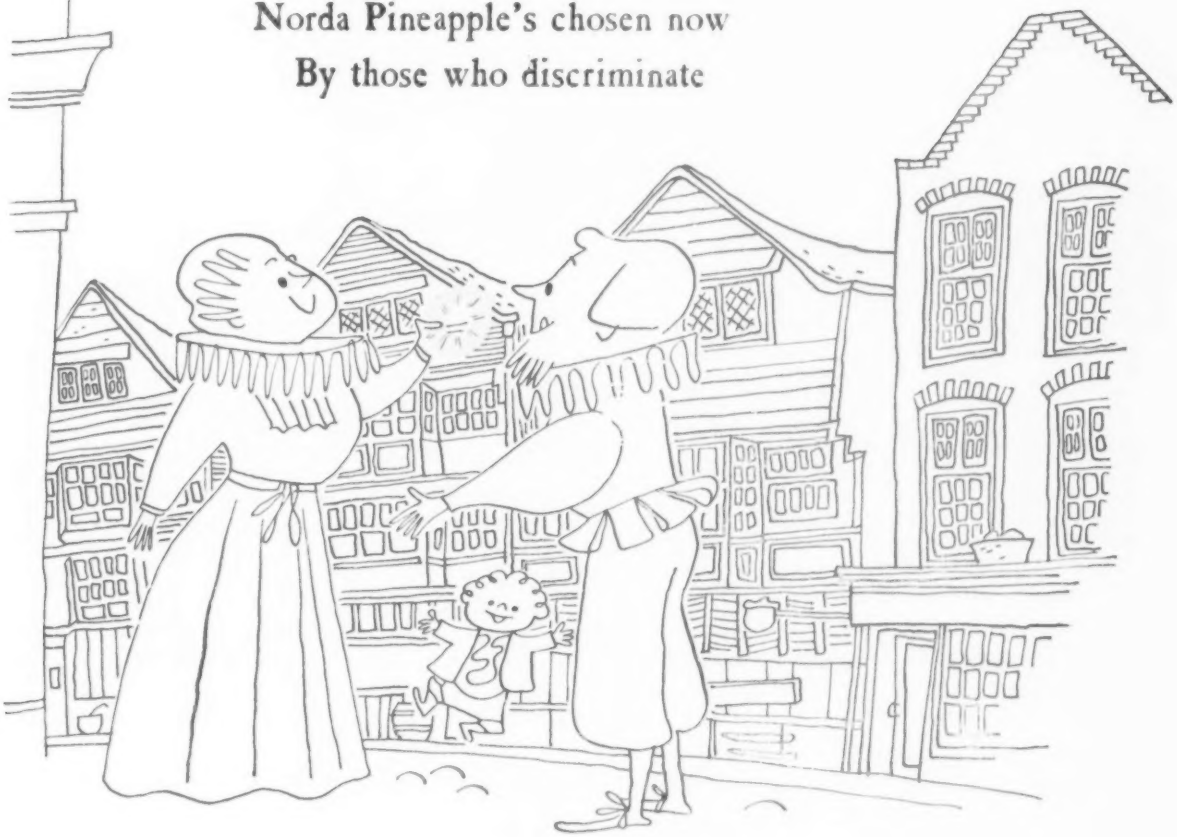

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DIAMOND CRYSTAL SALT with Antioxidant

Abstracts

(Continued from page 28)

in the aq. suspension of inhibited starch prior to the drying step, the dried inhibited starch-sugar mix obtained in the drum drying step being characterized by being relatively brittle and easily removable from the drum.

Starch conversion process.

NEWKIRK, W. B., AND DEOUHY, J. E. Assignors to Corn Products Refining Co. 2,610,132. September 9, 1952.

In the process of prepg. sirups from acid starch hydrolysate liquors having a D. E. value within the range of about 10 to about 32 by hydrolyzing starch with acid to a predetd. D. E. value followed by neutralization of the acid in the liquor to a pH of about 5 and refining and evapg. the liquor, the improvement which comprises adding to the liquor prior to neutralization a sufficient amt. of material from the group consisting of fatty acids derived from the hydrolysis of corn starch; fatty acids derived from the hydrolysis of sorghum grain starch; household soaps; sodium stearate; palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid, lignoceric acid, myristic acid, lauric acid, capric acid; sol. soaps derived from such acids, and mixts. of any of such soaps and acids, to react with the starch and/or starch-like bodies present to form a complex with the starch, cooling the liquor to a temp. within the range of about 60° F. to about 140° F. and maintaining the temp. of the cooled liquor within such range for at least one hr. and thereafter removing the fat-starch complex from the liquor.

PATENTS (BRITISH)

Preservation of eggs by freezing.

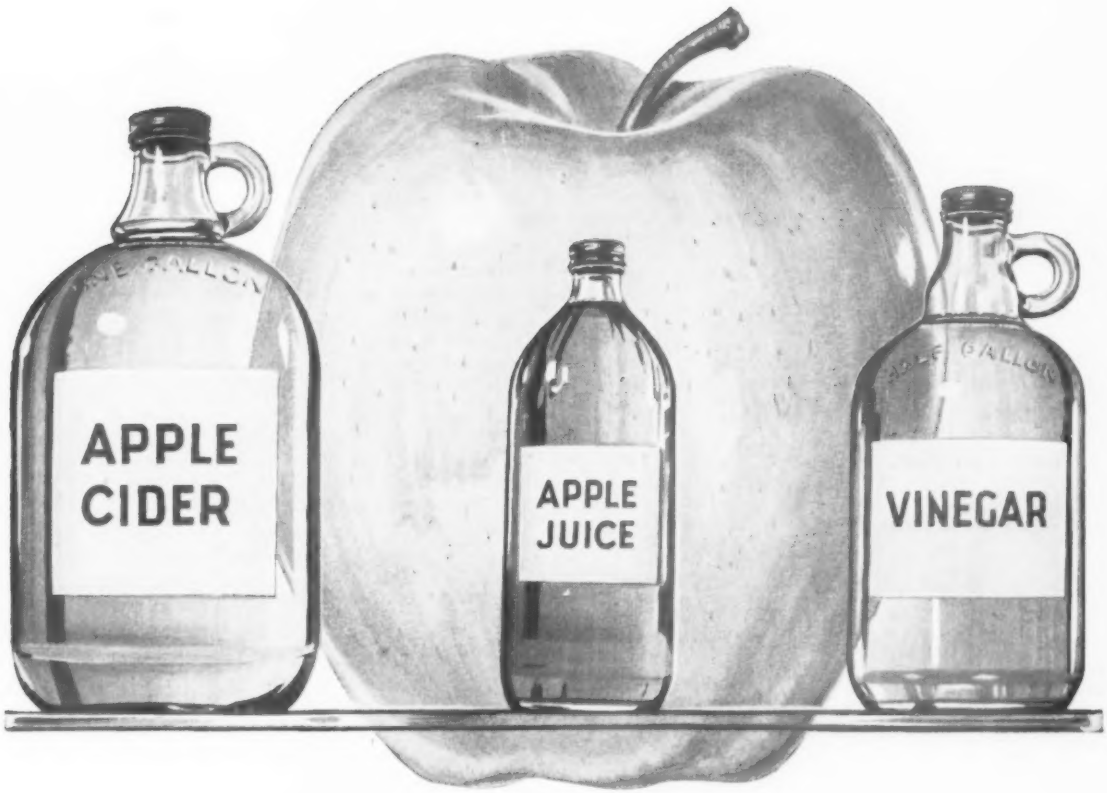
Board of Supervisors of Louisiana State University and Agricultural and Mechanical College. B. P. 667,375, 7/1/49; *Brit. Abstracts, B III*, 364 (1952).

The eggs are subjected to dehydration by diffusion or evaporation to reduce the wt. by 5-10% and, to facilitate the process, a preliminary treatment with dil. acid to increase the porosity of the shell may be carried out. Eggs so treated can be frozen without breaking the shells.

FUTURE DATES FOR FOOD TECHNOLOGISTS

1953	
March 1-6	National Frozen Food Convention, Chicago, Illinois
March 2-4	Quality Bakers of America, Chicago, Illinois
March 2-6	American Society for Testing Materials, Detroit, Michigan
March 8-11	American Institute of Chemical Engineers, Biloxi, Miss.
March 9-13	Statistical Quality Control School, University of Maryland, National Canners Association, Tri-State Packers, College Park, Maryland
March 15-18	One hundred and twenty-third National Meeting of the American Chemical Society, Los Angeles, California
March 19-20	National Collegiate-Industry-Government Conference on Instrumentation, Michigan State College, East Lansing (Invitational: Address Electrical Engineering Dep't., Michigan State College, East Lansing, Mich.)
March 22-24	American Dairy Association, Chicago, Illinois
April 6-10	American Society of Biological Chemists, Chicago, Illinois
April 6-10	American Institute of Nutrition, Chicago, Illinois
April 13-15	National Fisheries Institute, Washington, D. C.
April 20-22	American Management Association, National Packaging Exposition, Chicago, Illinois
April 20-22	National Frozen Food Industries Exposition, New York, N. Y.
May 4-6	Forty-fourth Annual Meeting of the American Oil Chemists' Society, New Orleans, La.
June 21-25	**Thirteenth Annual Meeting of the Institute of Food Technologists, Boston, Massachusetts**

(Information concerning future dates of national and international meetings, conventions and exhibits of interest to food technologists should be sent to the editorial office.)



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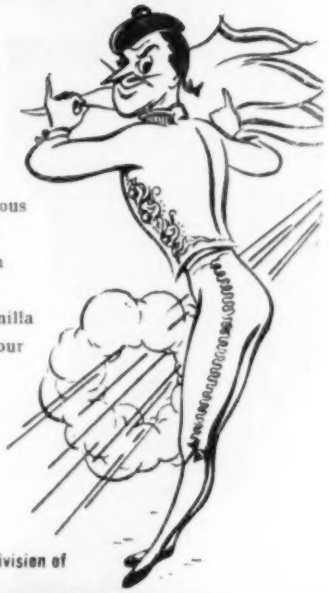

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FOOD CHEMIST, 30, Ph.D. in Nutrition, University of Toronto, 1953. 8 yrs. experience research and control in cereal industries, including packaging work. References. Available July. **REPLY BOX** 253, Institute of Food Technologists, 176 W. Adams St., Chicago 3, Ill.

WANTED: Food Technologist recent graduate, with excellent scientific and chemical engineering training and leadership potential. Challenging industrial work as Junior Assistant or Associate Technologist or processing engineer in successful food industry. Compensation and opportunity excellent for right man. **REPLY BOX** 255, Institute of Food Technologists, 176 W. Adams St., Chicago 3, Ill.

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THIRD SURVEY OF FOOD AND NUTRITION RESEARCH IN THE UNITED STATES

A third survey of food and nutrition research in the United States is being undertaken by the National Academy of Sciences-National Research Council under contract with the United States Department of Agriculture. The two previous surveys published in 1948 and 1950, and supported in part by Quartermaster Corps research funds, afforded a compilation of projects, organizations, and professional personnel then current in this field. All phases of food and nutrition research active in academic, governmental, and industrial laboratories were included. This consolidation of the research work and workers into a central register has afforded a unique basis for the coordination and evaluation of all research programs in the area. Its wide acceptance by individuals and organizations has served to minimize duplication of subject matter, wastage of the time of research personnel, and

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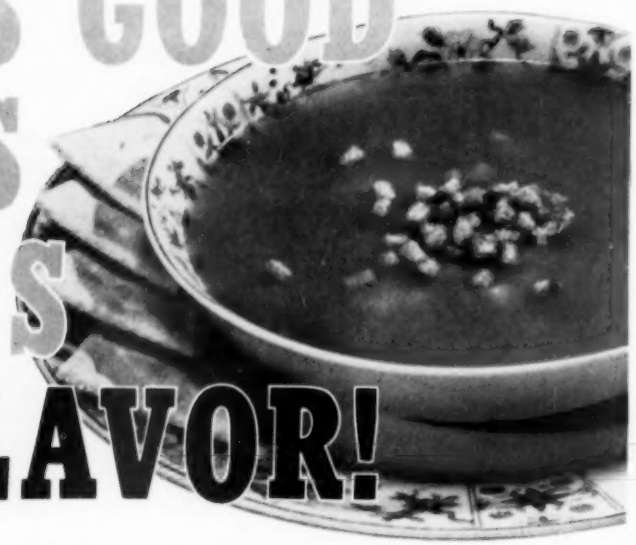

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inadequate coverage of research needs.

The third survey will follow the plan of the earlier surveys and will bring the information up to date. In addition, it will include suggested food and nutrition research projects in areas where further work is indicated.

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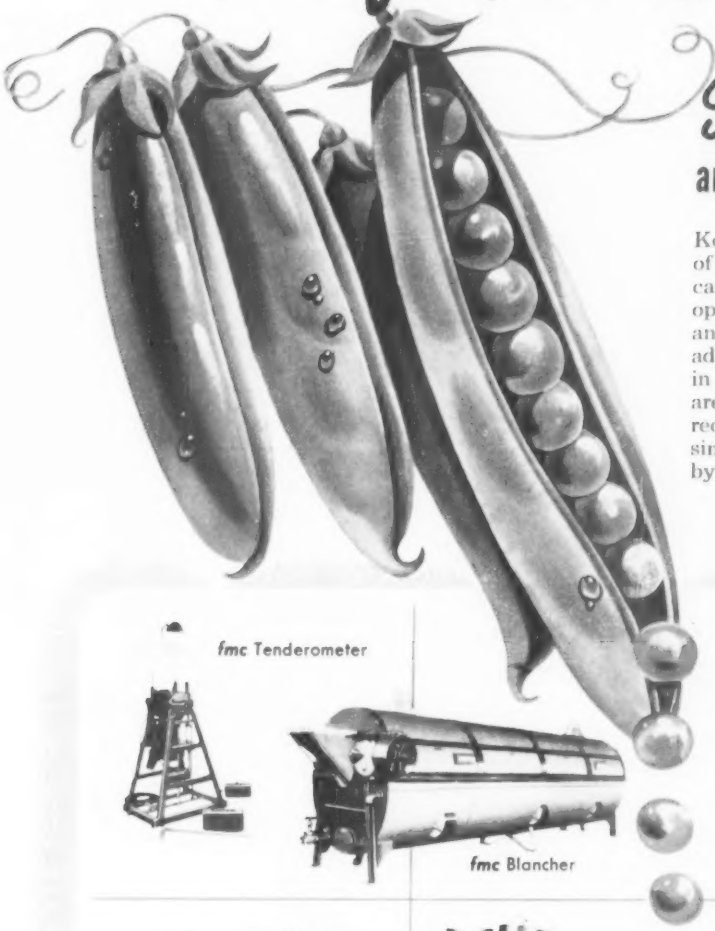

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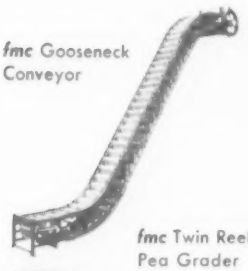

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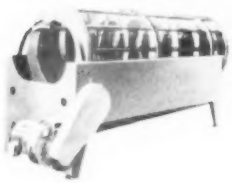

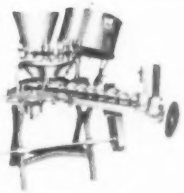

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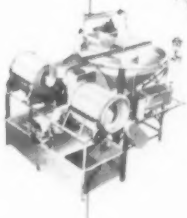

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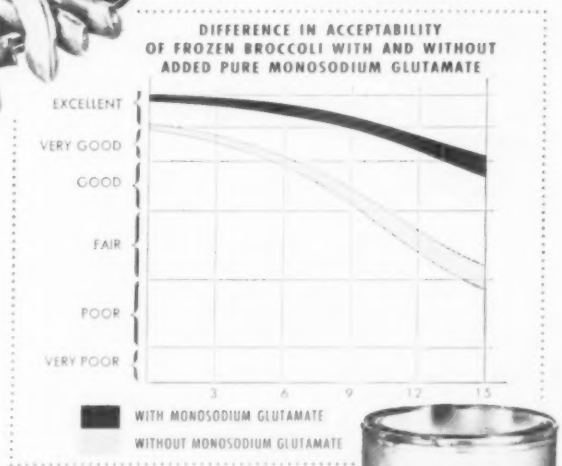

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